AMERICAN

Industrial

Hygiene

ASSOCIATION

Quarterly

AMERICAN

INDUSTRIAL HYGIENE

ASSOCIATION

Quarterly

Volume 15	SEPTEMBER, 1954	Number 3

New Developments ·
in Air Cleaning

LESLIE SILVERMAN, Sc.D.

Associate Professor, Industrial Hygiene Engineering, Industrial Hygiene Department
School of Public Health, Harvard University, Boston

THE GROWING concern over air pollution in major cities and from specific industrial sources has focused attention on air and gas cleaning developments. Such incidents as the recent Donora, London, Poza Rica and continued Los Angeles smog problems have emphasized the need for further knowledge and application of air and gas cleaning equipment.

The science of air and gas cleaning is not new since devices for removing particulate matter or gases and vapors have been applied in industry for at least 75 years. The important item, however, is that the character and variety of air and gas contaminants have changed in recent years and we are continually increasing the number of chemical and metallurgical agents which can pollute the atmosphere. In addition to the variety of contaminants now encountered we also have a marked reduction in particle size of discharged solid materials such as dusts, fumes and smokes. A number of extremely fine metallurgical and chemical particulates (less than 1 micron) are now a representative portion of the airborne material present in large industrial cities.

Since 1948, the Harvard Air Cleaning Laboratory has been studying air and gas cleaning methods under a U.S. Atomic Energy Commission contract. A large portion of the discussion given in this paper is centered around developments and studies made in our laboratory. Other new devices or modifications of older developments will also be considered.

Classification of Air Cleaners

AIR CLEANING devices are classified according to the forces which predominate in the separation of particulate matter. Basically they may be divided into inertial separators, filters, scrubbers or wet collectors, electrostatic precipitators and miscellaneous types. Included in the miscellaneous group are incineration, catalytic combustion, sonic and thermal agglomeration devices. Neither of the last two have proved very successful in commercial application to date. Thermal precipitation has not been used except for sampling purposes whereas sonic agglomeration, which has been tried on a pilot scale in recent years, has not proved outstanding in any large scale application.

All of the devices discussed in regard to specific types and applications are dependent upon the fundamental aerosol factors such as size, size distribution, shape, surface characteristics and specific gravity. In addition the aerosol loading or amount of material per unit volume of gas is important in the operating characteristics of each type to be discussed.

The important factors on any air or gas cleaner performance is its efficiency or ability to clean, its resistance or pressure loss when operating at design conditions and its useful life. The latter two factors are of paramount importance to plant operators since they are concerned with the economics of air and gas cleaning. From the pollution control standpoint efficiency or degree of removal is of the greatest significance.

Efficiency may be based on weight removal, discoloration of a given type of filter, or on a particle count basis. The first type of rating on a weight basis is of prime con-

cern in air pollution abatement whereas the other two methods are of importance in air conditioning or special applications.

It is not intended in this brief discussion to delineate all the reasons and factors involved in air and gas cleaner ratings and for that phase the reader is referred to the recent "Handbook on Air Cleaning"[1] or a recent article by the writer, "Performance of Industrial Aerosol Filters."[2]

In the field of inertial collectors, which is perhaps the oldest collecting device used, there is little that can be produced in the way of new equipment except those devices incorporating some new or novel approach to the old principle of applying as much centrifugal energy as possible to the particle. Attempts have been made in the power plant industry where these devices are used to the largest extent to increase the separating efficiency by decreasing the radius of travel of the particle as well as the use of multiple small devices in order to accomplish the objective of separation without undue pressure loss. The basic mechanism used in separating particles in inertial collectors, of course, is the terminal velocity of the particle which is a function of the 5 ess (s) factors: size, size distribution, shape, surface and specific gravity and somewhat less dependent on the gas viscosity and density. In this discussion, some new devices used for inertial separation will be discussed in regard to their recent application.

The area in which most progress has been made in the last decade has been in the field of filtration. The production of new media and different approaches to application of these media has resulted in some extremely efficient separating devices. Particle separation by filtration is a function of all of the particle parameters such as size, shape, specific gravity, surface, and electrostatic charge and, of course, the particle parameters are dependent upon the filter parameters such as fiber size, shape, charge and orientation or packing characteristics. Fundamentally, the forces which operate in the filter include those which operate in inertial collectors such as gravity and impaction but also include additional ones such as direct interception, diffusion, electrostatic charge, and possibly thermal precipitation.

Most of the new developments, with regard to filtration, have centered around the production of extremely fine fibrous media and the production of media having unusual surface, thermal, or electrostatic charge characteristics.

In the field of scrubbers or wet collectors there have been a few developments which may be of interest which have incorporated either the use of new filtration media or new devices for producing expanded surface for impaction and absorption. Wet collectors operate on principles similar to inertial collectors except that water or suitable absorbing solutions are provided in order to impact or retain particles whereby subsequent separation may then be made by inertial forces. Scrubbers may incorporate the principles employed in both inertial separators and filters and, in fact, several types of scrubbers employ packing which may also operate as a wetted filtration surface. Scrubbers are intended primarily for gas or vapor absorption but are often applied to gas and aerosol mixtures.

The development of fibrous media of inorganic materials such as glass in various sizes and forms and the production of monofilaments and fine fibers of several thermosetting resins or plastics have made possible extended surface absorption devices which can also incorporate filtration principles to assist in separation of both particulate and gaseous wastes. In this paper some new approaches in the application of wet cleaning will also be discussed.

The field of electrostatic precipitation will, of course, bring to light the fact that devices incorporating this principle depend upon charging of airborne particles and subsequent separation on charged plates by means of the induced charge. The predominant force in this method of separation is the electrostatic charge, its polarity and its magnitude. The conditions under which separation may take place are dependent upon the rate of air flow of velocity through the unit and the particle surface charge in relation to its mass.

In the past few years there have been considerable improvements in electrostatic precipitators and recently there have been introduced new separating approaches which utilize other than high voltage rectified current and which may use friction charged or electrostatically charged media
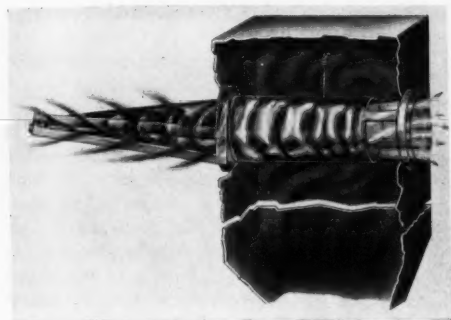
Fig. I.
New inertial collector (Amerclone) of small radius and unique design. (American Air Filter Company)

as a separating force. In this connection it is somewhat difficult to separate these latter types of electrostatic precipitators from filters but the distinction will be made in the text as to where the major separating force is applied in regard to the device in question.

Application of direct and catalytic combustion is the most recent development in the miscellaneous group. The problem of odor control from various solvents and off-gases especially from hot processes has made these devices attractive in the past few years. In this paper only a brief discussion of this method will be mentioned with some of its recent applications. Basically this method is primarily for gaseous wastes but in some instances it can be applied to particulates.

Inertial Separators Developments

THE INERTIAL or centrifugal separator, since this is the predominating force, is the oldest and simplest type of cleaner. For this reason the only new developments are in the form of design modifications. Because of the effectiveness of small radii in mechanical separation of fine particles most developments in recent years have utilized multiple small units. Basically, the smallest practical radius has been about 1½ to 2 inches. A very recent development[3] for removing solids from water has utilized smaller (0.4 or 0.6 inch) bakelite or rubber molded units in nest arrangements.

Basically, in air cleaning, the best size-separating characteristics have been obtained with the small two inch units which we found in our laboratory[4] will remove completely all particles above eight microns in size and approximately 50% of the particles in the two micron range, depending upon the specific gravity of the material involved.

The American Air Filter Company introduced the new Amerclone unit at the 1953 Chemical Show in Philadelphia (November). This device, shown in Fig. 1, is a small radius cyclone of novel design incorporating a heavy cast iron (⅜-inch) structure. It is intended primarily for power plant applications. It incorporates in the design a well shaped bell mouth entry and a decreasing radius separating cone. The heavy cast iron wall has proved necessary because of the abrasive character of power plant fly ash. Its performance is comparable to small radius cyclones and would yield values close to those cited above.

One additional development in inertial separators is the de Permentier strip type unit. This device consists of a series of flat extruded strips with semi-circular ends (see Fig. 2). The semi-circular ends form
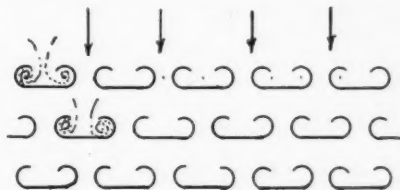
Fig. 2.
DEP (de Permentier) curtain type inertial separator.

small cyclonic sections for separation and the strips are placed in a vertical position with staggered rows. The bottom of the strips lead to collection hoppers. McCabe[5] has recently presented some data on the performance of these strips which can be made of extruded metal or plastics in a variety of sizes. Collection efficiencies for fly ash were as high as 80% by weight when 12 rows or grids were used. For cement dust 80 to 91.6% weight recovery was obtained on a dust with 38% of the particles less than 10 microns.

Filter Developments

FILTERS are the next most widely applied device for control of industrial process
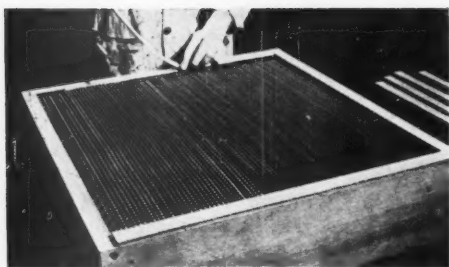
Fig. 3.
CC-6 space filter utilizing cellulose-asbestos or
glass fiber media.

waste air contaminants and receive the greatest application in home and office air cleaning. Basically filters can now be designed to give reasonably close to predicted removal and resistance values for a number of aerosols, however, most of those in use today are selected on an economical basis rather than any other factor.

In describing filter developments it is perhaps best to break down the newer innovations into new filtration media and then discuss devices or applications for these media.

In the inorganic fiber developments of the past two years we have had very fine glass fibers, ½ to 1 micron, produced commercially on a scale large enough to permit production of All-glass paper or webs in tonnage quantities. Glass web has been produced which has performance characteristics exceeding those of the so-called "ultra" or "absolute" filters made of cellulose and asbestos. Webs of the type known as MSA 1106B in 10 mil thickness (0.010") at a velocity of five feet per minute have an efficiency of 99.98% or penetration of 0.02% on dioctyl phthalate smoke which as a mean size of 0.3 micron. This web or fiber bonded mat has excellent resistance to most acids (except HF), will withstand 1000° F temperatures and has very high physical strength. The outstanding factor in connection with this web development is its relatively low cost as compared to early glass fiber developments.

Another recent fiber development is Fibrafrax, a product of the Carborundum Company. These fine fibers (1 micron and less) of aluminum silicate have been fabricated into webs also which give comparable

performance but will withstand temperatures up to 3000° F.

Both of these ceramic media can be fabricated into space filters such as those shown in Fig. 3 which permit low loadings (comparable to country air) of highly toxic aerosols to be cleaned with assurance that no significant effluent will penetrate. A 1000 cfm unit will occupy a space 2x2x1 feet. Some of these units have operated for as long as two years before replacement is necessary if they are adequately protected by a roughing or prefilter to remove heavy dust loads.

In the field of Fiberglas there has also been less efficient media produced with much lower resistance and longer potential life. This is the so-called Aerocor fiber group. These are phenol-formaldehyde resin bonded fiber mats made in 1 to 3 microns and 1 to 5 micron sizes with densities of 0.5 to 1 pound per cubic foot and one-half to one inch thickness. This material was originally intended for aircraft insulation but has since found application in air filtration work particularly for prefiltering air before the absolute filter mentioned above.

The Owens-Corning Fiberglas Company has recently introduced a unit comprised of bags made of this type of glass fiber which is to be used in series with the Dust-Stop or coarse glass fiber furnace filter. This combination makes ordinary filter banks nearly comparable in efficiency to two-stage low-voltage electrostatic precipitators.

We have recently developed[6] a filter utilizing the resiliency and performance of the resin bonded Fiberglas into a variable compression filter such as is shown in Figs. 4 and 5. This filter is designed for extended life and remote control for constant resistance. In essence it consists of a compressed bed of fibers which are arranged to filter radially. As resistance increases the compression is relaxed allowing further penetration of the media and increased porosity. We have been able to obtain at least four successive returns to initial resistance without affecting penetration. On atmospheric dust using one to three (PF 105) micron glass fibers efficiencies above 90% at 200 fpm filtering velocity have been obtained.

We have also studied the coarser media (PF 314) arranged in pleated form for a chemical hood or dry box application.[7] For
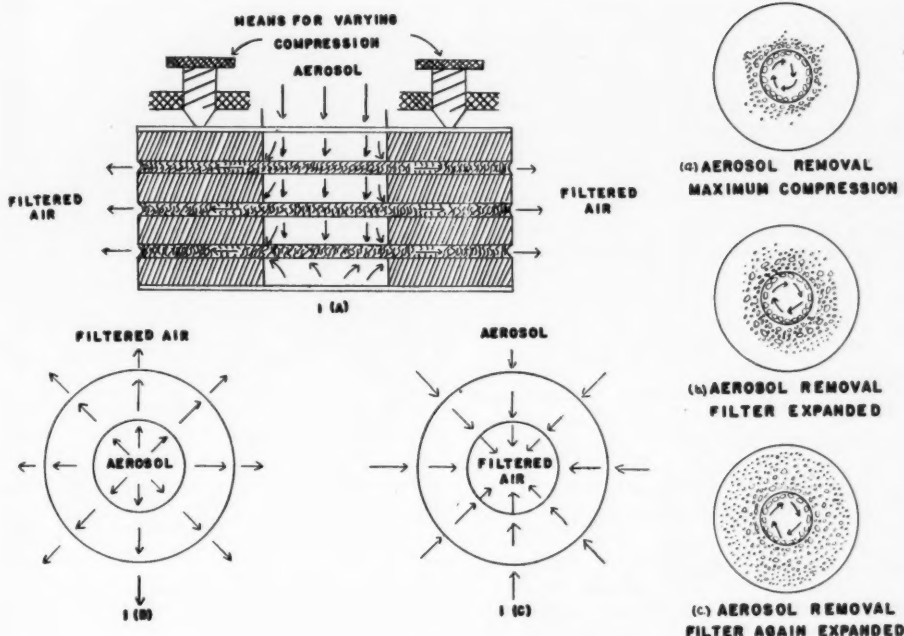
Fig. 4.
Variable compression or edge filter principle.

dusts comparable to atmospheric dusts in size this media will remove approximately 60 to 75% by weight and will thus increase the life of the final or absolute filters when they are used in conjunction with this prefilter.

One other application of the finer Aerocor (PF 105) media may be mentioned and that is its application as an absolute filter in the new Air Filter Institute Test equipment[8] as an absolute standard. Since a 0 to 5 micron fraction of dust is used as a standard test suspension this filter will show practically 100% removal by weight although it does not do quite as well on the usual encountered atmospheric dust.

The development of fine extruded or drawn resin fibers such as Saran, Dynel, Orlon, Dacron, etc., has indicated their possible application to air cleaners and our laboratory has been studying them as filter media for the past three years. Such fibers can develop a high electrostatic charge by friction charging (carding or combing). The effect of this charge on dust removal is
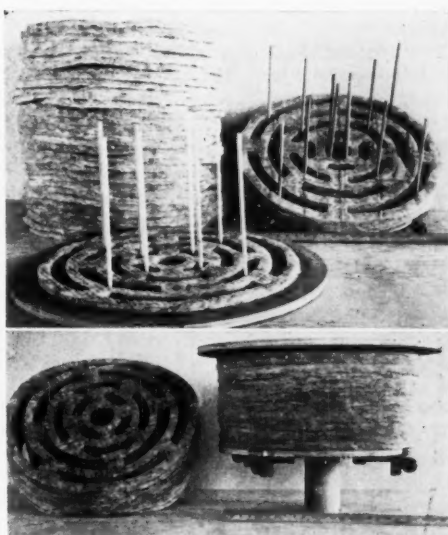
Fig. 5.
Model of variable compression filter designed to handle 2000 CFM of air.

primarily an electrostatic phenomena and will be discussed in that section. The fact that Dynel and Orlon can be produced in fibers of 6 to 10 microns and some even smaller makes their application to filtration as fibrous filters promising if production costs can be reduced. At the present time they are approximately $1.25 per pound in all various sizes. Recently felted material has been made from Dynel and Dacron fibers which offer promise in reverse-jet or bag filters for better chemical and temperature resistance than the wool media now widely used.

Ultra-fine plastic fibers for experimental purposes have been produced by textile development laboratories from polystyrene and nylon base materials and have been applied to plastic filter paper forming also on an experimental basis.

The wide variety of glass fibers in sizes and surface treatments has made possible their application to deep layer variable gradient filters. Such layers in depths up to 80 inches of 200 to 1 micron fibers in various densities and thicknesses have been used for cleaning atomic energy process off-gases with excellent results. Based on experimental data predicted performance has been followed for at least two years as recently reported by Blasewitz and Judson.[9] This application is for a low loading high toxicity aerosol with infrequent access desired.

A recent commercial innovation in the electrostatic filter field is the Goodyear Pliotron[10] filter. Since the filter is composed of $1/8$ to $3/16$ ribbons of polyethylene resin, its performance as an impaction filter is significantly less than the Dust-Stop or Amerglas glass fiber types which have glass fibers 25 microns and larger. Since its performance has been claimed as an electrostatic filter it will be discussed briefly in that group.

Wet Collectors and Scrubbers

IN THE CONTROL of process wastes it is frequently necessary to apply wet collection. The outstanding applications are for extremely high temperatures (above 400° F), chemical contaminants and mixtures of gases and particulates. While wet collectors have several disadvantages they do handle the above problems with excellent results
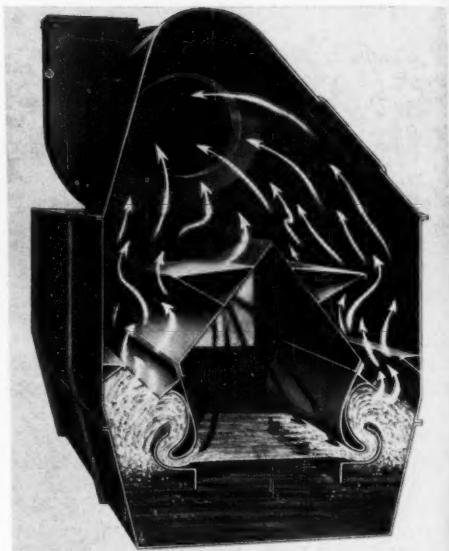
Fig. 6.
Modified Type N Rotoclone with improved entrainment separators and sludge ejection equipment.

in general and many types have been developed to increase their performance for small particle sizes.

In the simple inertial contactor unit the most recent improvement is the modified Type N Rotoclone (American Air Filter Company) shown in Fig. 6. This modification has improved entrainment separators and heavier sludge ejection equipment. Its performance is substantially the same but water carry-out and maintenance have been reduced.

In cyclonic scrubbers the most important factor has been the application of high pressure fog nozzles and recent studies by the writer[11] have indicated that the simplest high pressure fog nozzle operating at pressures of 400 pounds per square inch can recover as high as 70% of fine (0.3μ) ferrosilicon electric furnace fume at constant resistances of only 1 to 2 inches of water. Water consumption rates of these nozzles are relatively low but require clean or filtered water to minimize plugging and wear.

In the scrubber field the Harvard Air Cleaning Laboratory has recently developed two unique units. Both of these devices can

recover mixed contaminants efficiently. One of these described in a recent report[12] is intended for the recovery of fluorides as HF gas and particulate fluorides is a modification of the wet cell washer unit shown in Fig. 7. In the fluoride unit the wet cells have been packed with Saran or Dynel fibers and the dry pad for removal of fine particulates utilizes seven micron Dynel fiber.

For HF removal 178 μ, 78 μ, and 29 micron Saran pads in series showed mean efficiencies above 99% at air flow resistances of three to five inches of water. The water rate for a 20"x20" section was 8 gpm and the air velocity through the pad was as high as 216 feet per minute. A final fine fiber pad was found to be essential to remove the fine mist formed during scrubbing. Particulate removal was also accomplished by the series of filters varying in size and followed by a final dry pad. On bifluoride mist efficiencies approaching those for gas could be obtained. Ammonium bifluoride fume was removed at values approaching 99% with various Dynel fiber combinations.

Aluminum chloride and sulfuric acid mist can also be collected at values above 95% if ultra-fine fibers (1 μ) are incorporated in the final pad.

A unit based on the above principles can be designed as shown in Fig. 8 to effectively recover HF as a useful acid without elaborate treatment by using water as the absorbing liquid and scrubbing liquor.

A small unit incorporating the wet cell and an all-glass fiber eliminator plus a final all-glass filter was designed by Silverman and First[13,14] and built for handling perchloric acid in radioactive chemical work in laboratories. The device shown in Fig. 9 is constructed of stainless steel and will fit into a standard radio-chemical hood.[15] This unit, known as a "wet box" has been in effective operation for six months without
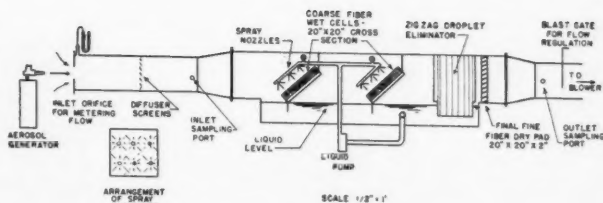
Fig. 7.
Wet cell unit packed with plastic fibers (Saran or Dynel) for HF and particulate fluoride removal.
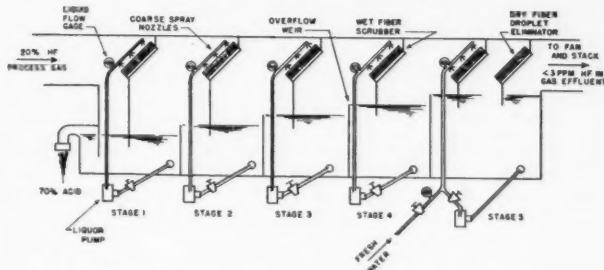
Fig. 8.
Hydrofluoric acid wet cell unit for stage absorption to yield 70% HF.

replacement of media until the end of that period. Failure of the aluminum separators due to alkali attack was the only defect and these have been replaced by steel. Efficiency of removal of perchloric acid mist and sulfuric acid mists ranged from 93 to 98%. Since no organic material is involved it adequately eliminates explosion and fire hazards and protects the final absolute filters from chemical attack.

Electrostatic Air Cleaner Progress

RECENT developments in the electrostatic field have not been numerous in the past two years. These devices exhibit the highest performance with minimal resistance of all the present types of air cleaning devices. Their cost has been such as to limit their application to those problems requiring efficiency independent of cost or to more effective precleaning of air for occupied spaces.

The high voltage field for process wastes has not seen any outstanding developments recently although two more foreign types have been produced by American manufacturers.

In the low loading field the Harvard Air
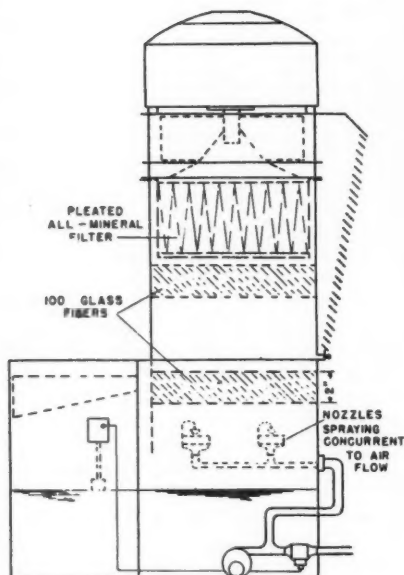
Fig. 9.
"Wet box" perchloric acid scrubber for radio-chemical laboratory hood use.

A — ORLON SCREEN
B — WOOL COVERED WIPER BLADE
C — ORLON COVERED PADDLE
D — PERFORATED LUCITE BOX
E — LUCITE ROLLER
F — WOOL BELT
G — MASONITE BOX

Fig. 10.
Two stage mechanically charged electrostatic fabric air filter utilizing wool and Orlon media.

Cleaning Laboratory has been working on devices for utilizing electrostatic forces at relatively low voltages (10 to 20 Kv.).

Tests have recently been completed on a device known as the Electro-Polar filter which uses a fine Fiberglas media (PF 316 or PF 105) for separation with a Dust-Stop prefilter. The Fiberglas media is placed between two expanded metal screens and a voltage differential of 12 to 15 Kv. is placed across the media. Our tests to date have indicated that electrifying or polarizing the media improves its efficiency on atmospheric dust and similar aerosols is approximately 10% absolute; viz., from 85 to 95%. This can also be interpreted as a reduction in effluent of 15 to 5% or a penetration reduction improvement of 300%. The resistance of the Fiberglas pad, however, is an important deterent in applying this device widely to general air cleaning problems. The effort to produce an electrostatic field around the fibrous media which without charge is a good basic filter at one inch pressure loss for 100 (PF 105) to 200 (PF 316) feet per minute may be questionable.

Mechanically charged filters under study at our laboratory have been of two types. One of these is the static type described by Rossano and Silverman[16] in which a bundle of plastic fibers is charged and its separation efficiency, resistance and life determined for inert and charged aerosols. The other is the continuously friction charged unit developed by Silverman, Conners and Anderson[17] in which mechanical friction charging of fibers at opposite ends of the tribo-electric series produces highly charged surfaces. Fig. 10 shows a schematic drawing of the first model of this device. Using a variety of combination of fabrics it has been possible to generate surface voltages approaching 20 Kv. Separation efficiency with this device on atmospheric dust by discoloration tests has indicated efficiencies approaching 80%. Further improvements of this device are under investigation at the present time at the Harvard Air Cleaning Laboratory.

Electrostatic filters of the static type such as the resin wool filter developed in Denmark and used as a gas mask filter in World War II by the British has also been applied to the problem of air cleaning of normal atmospheric dust. The results of tests which the author has described in a recent publication[2] have indicated that resin wool felt is significantly better than ordinary wool felts but continued tests indicate that the life of the charged resin is quite short on atmospheric dust removal.

The most recent development in this category is the so-called electrostatically charged filter introduced on the market by the Good-

year Tire and Rubber Company. This device consists of a frame packed with randomly placed polyethylene strips of rectangular cross-section, approximately ⅛ to 3/32 of an inch. It is claimed by the manufacturer that this filter is charged by the dust passing through it. Our experience with this device in the laboratory has indicated that its discoloration efficiency is less than 10% and is not significantly greater than the ordinary impingement type filter. There was no evidence of surface charge on the filter fibers when received and no charge increase was measured during or after running. For the past four years we have been studying synthetic resins[16] as electrostatic filters on which a static charge was placed by mechanical carding. This, we found, produces a high initial charge which is effective in removing dust but the charge dissipates with continued filtration. This then means that the charge is dissipated by the atmospheric dust and ion passage rather than increased. It is difficult to understand how the amount of energy in atmospheric dust at relatively low velocities can contribute much to mechanical charging of a filter. However, further tests of this type of filter is progressing. Indications to date are that mechanical charging is beneficial and may depend on the type of resin and its properties. Resin wool felts have been available on the American market and used in respirators but have not received much attention in general air cleaning. Most of the synthetic fibers are highly charged during their manufacture and the problem then is to dampen or depress this charge. Usual methods of electrostatic control or putting a surface active agent directly onto the fibers is used to minimize the charge.

Incineration

IN THE FIELD of incineration or combustion of waste gases, the principal applications have been in handling odor problems. The most noteworthy development in recent years has been the application of catalytic combustion to the methods previously employed. Catalytic combustion in practice has utilized two devices; one which utilizes a Berl or ceramic saddle coated with a platinum catalyst; the other, ribbons of platinum or noble metal mounted in the form of a filter frame. Both of these devices require

temperatures of 500° or more before the catalyst will create burning in the gases. In some cases, application has been made of the amount of heat recovered from such a process but it should be borne in mind that if such quantities of heat can be developed then the quantities of solvent or vapor which are being lost are quite high and possibly the use of solid adsorbents such as activated charcoal could have been considered unless the capital investment was beyond the reach of the manufacturer. Not to be overlooked even though catalytic combustion can be applied, is the possibility of using high temperature combustion sources that are already available in many instances. In the writer's recent experience the problem of odors from fish meal processing plants indicated that the problem could be solved by direct combustion under the steam plant fire box if the volume of gases being removed from the process was kept to a minimum and the richer concentration of gases were supplied as combustion air to the boiler plant. Experience has shown that each gallon of oil burned per hour will handle approximately 50 cubic feet per minute of waste gas at standard temperatures based on 100% excess air for combustion. In applications where this method has been applied to eliminate odors, the direct combustion method has proved effective and previously used scrubbing methods with chlorine treated water or chlorine dioxide did not provide satisfactory control. Catalytic combustion has promise if the heat to be supplied to bring temperatures to 500° F is not excessive and if gases involved when burned do not poison the catalyst while undergoing conversion.

References

1. FRIEDLANDER, S. K., SILVERMAN, L., FIRST, M. W. and DRINKER, P.: Handbook on Air Cleaning. U.S. Government Printing Office, Superintendent of Documents, Washington, D.C., 1952.

2. SILVERMAN, L.: Performance of Industrial Aerosol Filters. *Chem. Eng. Progress*, 47:462, 1951.

3. ANONYMOUS: These Are Production Cyclones. *Chem. Eng.*, 60:218, 1953. Also The Dorr Company, TM Dorrclone, Bulletin 2502, Stamford, Connecticut.

4. DENNIS, R., COLEMAN, R. D., SILVERMAN, L. and FIRST, M. W.: Particle Size Efficiency Studies on a Design Two Aerotec Tube. NYO Report No. 1583, U.S. Atomic Energy Commission, April 1, 1952.

5. McCABE, L. C.: Atmospheric Pollution. *Ind. and Eng. Chem.*, 44:123a, 1952.

6. SILVERMAN, L. and FIRST, M. W.: Edge and Variable Compression Filters for Aerosols. *Ind. and Eng. Chem.*, 44:2777, 1952.

7. SILVERMAN, L., FIRST, M. W. and LaTORRE, P.: Efficiency Studies of Fiberglas Prefilters for Chemical and Laboratory Hoods. NYO Report No. 1584, U.S. Atomic Energy Commission, June 6, 1952.

8. ANONYMOUS: Air Filter Institute Test Code. *Heating and Ventilating*, 50:134, 1953.

9. BLASEWITZ, A. G. and JUDSON, B. F.: Filtration of Radioactive Aerosols by Glass Fibers. Paper presented at 46th Annual Meeting of the American Institute of Chemical Engineers, December 16, 1953, St. Louis.

10. VAN ORMAN, W. T. and ENDRES, H. A.: Self-charging Electrostatic Air Filters. *ASH&VE Journal Section, Heating, Piping and Air Conditioning*, 24:157, 1952.

11. SILVERMAN, L. and DAVIDSON, R. A.: Collection of Fumes from Ferrosilicon Electric Furnace Operations. Paper presented at Annual Meeting of the American Institute of Mining and Metallurgical Engineers, New York, New York, February 17, 1954.

12. BERLY, E. M., FIRST, M. W. and SILVERMAN, L.:

Removal of Soluble Gases and Particulates from Air Streams (with special reference to fluorides). NYO Report No. 1585, U.S. Atomic Energy Commission, October 24, 1952.

13. FIRST, M. W., *et al.*: Air Cleaning Studies. Annual Report 1951-1952. NYO Report No. 1586, U.S. Atomic Energy Commission, February 16, 1953.

14. SILVERMAN, L. and FIRST, M. W.: Hood Scrubber Unit for Perchloric Acid. NYO Report. In press 1954.

15. ROBERTS, C. P.: Air Supply and Exhaust in Laboratories Handling Radioactive Materials. Proceedings— Laboratory Design for handling radioactive materials, May 1952. Building Research Advisory Board. National Research Council, Washington, D.C.

16. ROSSANO, A. T., JR. and SILVERMAN, L.: Electrostatic Effects in Fiber Filters for Areosols. *Heating and Ventilating*, 51:102 (May) 1954.

17. SILVERMAN, L., CONNERS, E. W. and ANDERSON, D.: Mechanical Electrostatic Charging of Fabrics for air Filters. Manuscript in preparation, 1954.

British Occupational Hygiene Conference

THE THIRD CONFERENCE of the British Occupational Hygiene Society will be held at the London School of Hygiene and Tropical Medicine on the 1st of November. The Conference will be devoted to a discussion of radiation hazards in industry. The preliminary program is as follows:

"The Health of Workers Exposed to Ionizing Radiation" by A. S. McLEAN, M.B., Ch.B., D.I.H., Principal Medical Officer, Department of Atomic Energy, Industrial Group.

"Radiation Safety in the Industrial Group of the Department of Atomic Energy" by D. R. R. FAIR, O.B.E., B.Sc., A.Inst.P., Head of the Health Physics Division, Department of Atomic Energy, Industrial Group, Windscale Works, Sellafield.

"Protection against X-rays and Gamma-rays in the Industrial Field" by W. BINKS, M.Sc., F.Inst.P., Radiological Protection Service, Ministry of Health and Medical Research Council.

"Safety Criteria in Atomic Energy" by F. R. FARMER, B.A., Assistant Director (Production), Atomic Energy Industrial Group Headquarters, Risley.

The final program and form of application for the Conference may be obtained from the Society's Hon. Secretary, P. C. G. ISAAC, Public Health Engineering Laboratory, King's College, Newcastle upon Tyne.

Air
Re-
ber

ual
mic

ber

ab-
s—
als,
nal

ro-
and

on,
for

Dust Concentrations in a Foundry

—A STUDY IN TEMPORAL VARIATIONS

HOWARD J. SCOTT, JR., Supervisor, Safety Department
Goodyear Atomic Corporation, Portsmouth, Ohio
LESTER M. MERRITT, Industrial Hygiene Engineer
Division of Safety and Hygiene, Industrial Commission of Ohio

IN USING dust counts to determine dust exposure hazards, the question frequently arises as to the reliability of one or even several samples as a basis for evaluation. It is argued that the dust concentrations at a given location may vary extensively from hour to hour, day to day, or week to week. Brandt,[1] giving credence to this argument, suggests that a minimum of three good samples be taken on three different days to evaluate one exposure.

In order to investigate the extent of such temporal variations in dust concentrations under actual field conditions, a six-week study was made in a large steel casting foundry engaged in the manufacture of parts for railroad cars. A specific test lo-

cation was selected in each of nine representative work areas in the foundry. In each area, the work performed was of a repetitive nature, remaining essentially the same from day to day and week to week.

Dust samples were taken in precisely the same manner at each of these nine test locations once each week for six successive weeks. In order to minimize possible effects of variations in temperature and humidity or changes in work tempo, the sample at each location was taken at the same time in the morning and on the same day of the week throughout the study. A small electric motor-driven suction pump was used to pull 0.1 cubic feet of air per minute through midget impingers (described in Bureau of Mines Information Circular 7076). All tests were for five-minute periods and ventilation conditions remained the same throughout the six-week study.

The dust-containing liquids in the im-

TABLE I.
TEMPORAL VARIABILITY IN DUST CONCENTRATIONS IN A FOUNDRY

| Test Location and Description of Work Area | Dust Concentration in Million Particles per Cu. Ft. | | | | | | | |
| | Week of Study | | | | | | Average | Range |
	1	2	3	4	5	6		
No. 1—Sand Slinger Molding Area: Sand slinger operating intermittently 10 to 75 ft. distant.	6.6	8.0	3.0	9.2	3.4	1.9	5.4	1.9- 9.2
No. 2—Molding Gang Area: Two molding machines 12 and 30 feet distant.	24.8	7.4	4.5	7.7	27.4	7.4	13.2	4.5-27.4
No. 3—Molding Gang Area: Adjacent equipment not operated during study; active operations 125 ft. distant.	11.3	4.2	7.1	4.7	28.3	12.1	11.3	4.2-28.3
No. 4—Aisleway in Core Room: Core compound mixer 75 ft. distant.	3.1	3.0	3.5	7.0	6.3	5.4	4.7	3.0- 7.0
No. 5—Coupler Building: Portable grinders and chipping hammers adjacent.	7.7	4.3	9.2	8.4	3.8	5.1	6.4	3.8- 9.2
No. 6—Coupler Building: Portable grinders and shot blast room adjacent.	10.0	16.7	4.8	15.0	9.6	9.6	11.0	4.8-16.7
No. 7—Bolster and Frame Building: Shot blast room, grinders, chipping hammers adjacent.	8.6	6.2	5.2	7.2	2.8	2.9	5.5	2.8- 8.6
No. 8—Bolster and Frame Building: Swinging grinders adjacent.	8.2	9.9	9.3	5.3	4.2	4.6	6.9	4.2- 9.9
No. 9—Port End Repairs Area: Handling of silica bricks in repairing port ends.	7.7	5.1	10.2	8.6	14.6	6.4	8.8	5.1-14.6

pinger flasks were made up to 10 or 20 milliliters (depending on expected dust concentration) by adding dust-free isopropyl alcohol. Counting cells, one millimeter deep, were then filled from the well-mixed, diluted samples and allowed to settle for at least 20 minutes. Five fields in the cell from each sample were counted using the microprojection method.[2] Dust concentration in millions of particles per cubic foot of air sampled was then calculated from the volume of air sampled, the average count per 0.25 cubic millimeter of the diluted liquid, and the dilution factor.

As shown in Table I, large variations in dust concentrations occurred at each of the nine locations despite the fact that production and ventilation conditions remained essentially the same throughout the study. The slight variations in temperature and barometric pressure that occurred from one week to the next during the study were carefully recorded but exhibited no correlation with variations in dust concentrations.

These data clearly demonstrate the errors that can result if a single sample is used to evaluate a dust exposure hazard. For example, an evaluation based solely upon the sample collected at Location No. 3 during the second week (4.2 million particles per cubic foot) would differ considerably from an evaluation based solely upon the sample collected at the same location during the fifth week (28.3 million particles per cubic foot).

It is therefore concluded that one dust sample, in the absence of additional evidence, is inadequate to permit a reliable evaluation of a dust exposure hazard. And even several samples, if taken within a relatively short period of time, should not be accepted as conclusive.

References

1. BRANDT, A. D.: Industrial Health Engineering, Chapter II. New York: John Wiley & Sons, Inc., 1947.

2. BROWN, C. E., *et al.*: Microprojection Method for Counting Impinger Dust Samples. U.S. Bureau of Mines, *Report of Investigations*, 3373, Department of the Interior, Washington, D.C., 1938.

Industrial Medicine at Southern Cal

FOR SOUTHERN CALIFORNIA doctors, industrial nurses, industrial hygienists, attorneys, claims adjusters and interested persons in industry, University of California Extension this fall will inaugurate a course in "The Application of the Principles of Industrial Medicine to Private Practice." Meeting place for the unusual course will be the University Extension center, 813 South Hill Street, in downtown Los Angeles, where a fall session will meet on Wednesdays from 7:30 to 9:30, October 13 through December 8, 1954 and a spring session, from February 2 to March 23, 1955. Applications or requests for information should be made to Thomas H. Sternberg, M.D., Head of the Division of Postgraduate Medical Education, University of California Medical Center, Los Angeles 24. Fee for the course is $40 each for the fall and spring sessions. Because 90% of industrial medical patients are handled by physicians in private practice, the University Extension course is primarily designed to present the theory and principles of industrial medicine to private physicians engaged partially or principally in this type of practice, points out Dr. Sternberg. It will also give the student who is not a specialist comprehensive knowledge of specialized problems. Lecture topics during the fall semester will include "Legislative and Legal Factors in Industrial Medicine"; "Medical Reporting, the 'Paper Work' Involved"; "The Human Relationship Problem in Industrial Medicine"; and "The Pre-Employment Examination and Job Placement."

Evaluation of Laboratory Fume Hoods

H. F. SCHULTE, E. C. HYATT, H. S. JORDAN and R. N. MITCHELL
Industrial Hygiene Group, Los Alamos Scientific Laboratory
Los Alamos, New Mexico

A N EVALUATION of laboratory fume hoods was originally undertaken with the aim of obtaining data on the numerous types of existing hoods at Los Alamos and for developing design specifications for new hoods. In no instance in the field of hood application is the designer asked to reconcile as many contradictory requirements as in the design of laboratory fume hoods. For this reason, there are many custombuilt hoods offered for sale and fume hoods appear to serve as favored subjects for advertising copy. The word "fume" in this paper is meant to include vapors, gases, smokes, mists and other airborne materials.

Design Data and Test Methods

A SURVEY of the literature showed that the only design criterion specified in various handbooks was that of face velocity and the recommended value of this varied from 50 to 150 feet per minute.[1,2,3] Even the manual on industrial ventilation of the American Conference of Governmental Industrial Hygienists which has become a standard reference work contains little but contradictory information on this equipment.[1] Stockdale and Turner studied several hood types by means of smoke tests and developed a hood which they state operates satisfactorily at 50 feet per minute face velocity.[4,5] Others also have used combinations of smoke and face velocity tests.[5,6,7,8] An inquiry addressed to hood manufacturers regarding their methods of testing yielded absolutely no information.

Proposed Method of Testing

T HE PRINCIPAL criterion of hood performance is the effectiveness with which fumes are captured, retained and exhausted

under normal conditions of use. Normal use in this sense would include average room air currents, activity of personnel in front of and partially inside the hood, and the generation of fumes in almost any part of the hood. The desirable air pattern for a hood, therefore, is one with a stable, continuous flow of air from the face to the exhaust slots. Any feature which causes the air to become unstable and change direction would be undesirable.

Smoke for the study of flow patterns was generated by means of five-minute smoke candles and also by means of the unit shown in Fig. 1 which burns a mixture of sawdust and motor oil. An attempt was made to develop an odor test to give quantitative results but this was unsuccessful. The test procedure used was to observe the flow patterns revealed by smoke generated in various parts of the hood under varying operating conditions. These conditions included different face velocities, cross draft velocities, thermal loadings, slot openings, en-
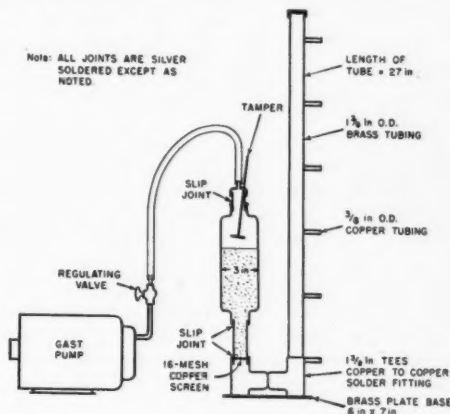
Fig. I.
Smoke generator.
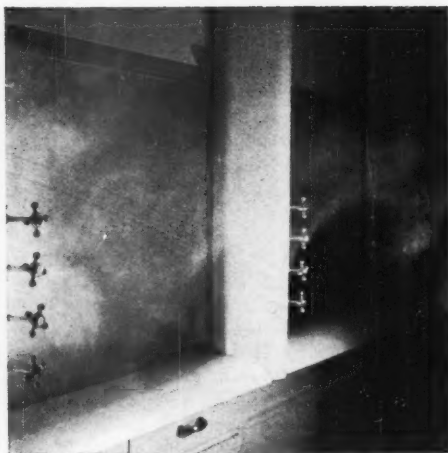
Fig. 2.
Effect of cross draft velocity in excess of the face velocity.

trance shapes and others where such factors could be varied on specific hoods.

Results

Cross Currents and Face Velocities— Studies indicated that cross currents and other random air movements are a major factor affecting the stability of the air flow within the hood. It was found that whenever the velocity of the cross currents equals or exceeds the face velocity, serious disturbances of the hood air flow pattern results. The degree of this disturbance is practically independent of hood design. To insure proper performance of a hood under conditions of normal use, the face velocity thus must exceed the expected cross draft velocity, which means a design face velocity of at least 100 feet per minute. This is based on actual measurements of cross drafts and air movements produced by operating personnel. Velocities less than this value do not provide adequate control under normal conditions of use. Conservation of heated or cooled air at the expense of an adequate control velocity simply is not justified. In this investigation, controlled cross drafts were induced with a variable speed fan and were measured parallel to the face of the hood with a velometer. The effect of cross draft velocity in excess of face velocity is illustrated in Fig. 2.

It is this detrimental effect of cross drafts

which nullifies attempts to provide an independent source of unconditioned or untempered air to a hood. Tests were made on one hood where air was brought in along the sides and top of the hood face to supply about one half of the total amount of air exhausted by the hood. Smoke tests on this hood are shown in Fig. 3. Correspondence with other engineers and observations made in other laboratories have convinced us that the independent air supply is not a solution to the problem of saving heated or cooled air.

*Location of Hood in Room—*Careful consideration should be given to the location of the hood in the laboratory, although here many compromises have to be made. It is desirable to minimize the effects of thermal air currents from heating units and currents from doors, windows and supplied air inlets. A perforated ceiling as a supplied air source to a room was found to be almost ideal in its noninterference with hood operations.[5,9]

Tests on one recessed radiator showed air currents with velocities as high as 100 feet per minute which would seriously interfere with the hood operation. Also, heat from a radiator located near a hood is largely wasted through the hood exhaust. Since most hoods will be used for operations that potentially may result in a fire or explosion, the hood should be located so that the exit from the laboratory will not be blocked in case of such an accident in the hood.

*Thermal Loading—*It has been reported
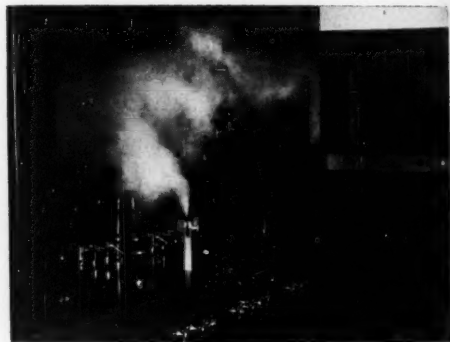
Fig. 3.
Smoke test on hood having untempered air supplied through grills on side and top of hood face.

that heavy thermal loads inside a hood cause large variations in hood performance.[10,11] To test this, a hood with a work surface 2'x3', a face area 2½'x3' and an average face velocity of 80 feet per minute was equipped with three 1200 W hot plates and four Meeker burners. With only the hot plates in use, the air temperature in the upper part of the hood was 8° C. above room temperature and there was no effect on flow pattern or face velocity distribution. There was no leakage of smoke from the upper part of the hood. With the four Meeker burners operating as well as the hot plates, the upper air temperature reached 38° C. above room temperature. Again, there was no adverse effect on flow pattern or face velocity. This is illustrated in Fig. 4. However, there was an appreciable leakage of smoke around a poorly fitted by-pass damper in the upper part of the front of the hood. This is due to the thermal head created by the difference in density between the heated air inside the hood and the air outside. This thermal head is larger than the small static suction required to pull air into the hood.

Repeating these same tests at a face velocity of 50 feet per minute, again, showed no effect of heat on the face velocity but an unfavorable effect on the air flow pattern. The leakage of smoke was considerably increased and some even leaked out of the upper part of the hood face. Obviously, this is an extremely heavy thermal loading and is much more severe than is likely to be encountered in actual practice. In the test
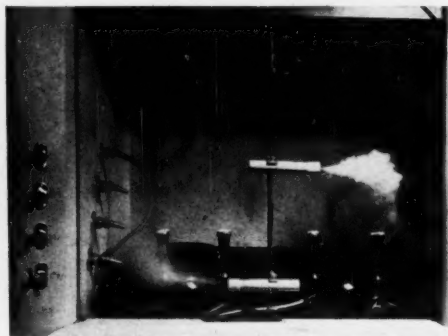
Fig. 4.
Smoke test showing lack of effect of high thermal loading on air flow pattern.

Fig. 5.
Air currents moving toward the hood face along the side walls and bottom of a hood with corner posts and depressed base.

procedure, all hoods were tested with a thermal loading of one Meeker burner per foot of hood length and in no case was there a serious disturbance of the air flow pattern.

Entrance Shapes—The study revealed that any plane surface intersecting the air stream would cause serious disturbance of the air flow pattern within the hood and, in many cases, cause air to flow toward the face of the hood. If such a disturbing surface is at or near the hood face these air currents may be quite serious. For this reason, hoods without corner posts, center posts or excessively depressed bottoms were found to give the best pattern of air flow. Hoods that have such obstructions have currents of air moving along the side walls and bottom toward the face of the hood as illustrated in Fig. 5. Fumes captured in these currents will move toward the face and be recaptured by the main air stream only at the very edge of the hood opening. Under these conditions, the slightest external disturbance by cross drafts will actually aspirate such fumes out into the laboratory.

The inside of the front of the hood above the opening is another surface that will cause air to move toward the face. Fumes captured in this air flow will run down this

Fig. 6.
Smoke moving down the inside surface of the hood and being recaptured at the face opening.

A. PLAN VIEW OF HOOD
WITH CORNER POSTS

B. PLAN VIEW OF HOOD
WITH PLAIN ENTRANCE

C. PLAN VIEW OF HOOD
WITH AIRFOIL ENTRANCE

D. PROFILE OF HOOD SHOWING
RUNDOWN, SAG AND DEPRESSED
BASE

Fig. 7.
Air flow patterns in hood.

surface and form a sag of variable depth before being recaptured by the incoming air again, at the face of the hood. This is illustrated in Fig. 6. Tests on one hood indicated that an air foil along the top of the hood opening or streamlining the top of the hood had no practical value in improving this condition, at least within the limits imposed by the operations carried on inside the hood. Sinks were found to create unfavorable air patterns and it is felt that the front side of any sink should be a minimum of six inches back from the face of the hood. Hoods, therefore, should have a smooth and as continuous a surface as possible. Air foils along the side and bottom of the hood entrance improve the air flow somewhat by eliminating the vena contracta. With face velocities of 80 to 100 feet per minute, an ordinary unobstructed entrance will create a vena contracta about six inches inside the hood face and extending to within one inch of the side walls. This will cause a slight disturbance to any fumes generated right at the edge of the hood and this condition could be corrected by air foils. It is doubtful, however, that the installation of air foils could be justified if the cost was appreciably in excess of that required for

an ordinary unobstructed entrance. Fig. 7 illustrates the air flow pattern in these various hood types.

Doors and By-Passes—The matter of doors on a laboratory fume hood is largely one of personal preference. There is no doubt that they represent a convenient safety shield that may be put into place quickly. However, as far as the action of the hood itself is concerned, it is doubtful whether doors aid in any manner. It is felt that hoods equipped with doors also should be equipped with some sort of by-pass to minimize fluctuations in the face velocity of the hood and in the amount of air supplied to the laboratory. Our tests verify the generally accepted fact that velocities in excess of 300 feet per minute will seriously disturb flames and powders in the hood. By-passes must be carefully designed and constructed. The type of by-pass actuated by means of a mechanical linkage has proven superior to gravity-operated or electronically controlled by-passes. The gravity-type by-pass similar to a furnace draft damper has the disadvantage of not forming a fume-tight seal in the top of the hood and does not give completely satisfactory control over the face velocity. The differential pressure produced by the low rate of air flow into the hood is not sufficient to make the by-pass a positive acting one. Extreme precision is needed in the mounting and bearing assembly of such a by-pass if it is to function satisfactorily. A system of hoods

each equipped with an electronically controlled by-pass was included in this study. The operation of the electronic controls was highly unstable and the mechanism tended to "hunt" continuously. It became necessary to disconnect all controls and servo motors and lock the control damper in a fixed position.

Slots and Plenums—An ideal laboratory fume hood would be exhausted through the entire back of the hood and then directly outside. Normally, however, the space behind the hood is limited and the exhausted air must be carried by ducts upward or downward from the hood. Thus, it is common practice to exhaust through slots in the rear usually located at the top and bottom of the rear wall of the hood. The slots may have individual ducts or may be open into a plenum behind the hood. The relative amounts of air flowing through each of the two slots are usually made adjustable to provide for an even distribution of face velocity. This may be done either by making the slot width adjustable or by dampers in individual ducts leading to each slot. The former method is least desirable since the adjustment is readily and frequently made by the user who has no air flow instruments to check on the adjustment. As a result, such hoods are usually found out of balance. Also, in many

cases, the depth of the plenum behind the hood may be smaller than the slot width and, hence, little is accomplished by small adjustments of the slot width. The most satisfactory arrangement appears to be a separate duct of proper design for each slot with a control damper in each duct.

Location of Blowers—Normally, a hood will be utilized to control a toxic or irritant substance and, therefore, it will be undesirable for such a substance to escape from a hood or from a conveying duct before reaching the discharge point outside the building. Hoods should have the blower located at the discharge end in order to maintain a negative pressure in the conveying ducts.[12] Generally, this is not a problem when hoods are connected together in an exhaust system. Unfortunately, it seems to be a prevailing practice to install individual blowers in a housing immediately above the hood proper.

Exhaust Ducts—Experience at Los Alamos would seem to indicate that down draft hoods with ducts underneath the floor give little trouble from condensation. It is also an easier task to maintain washdown sprays in such ducts. Hoods connected to overhead ducts have given trouble due to condensation and scale particles falling back into the hood. Therefore, if hoods are to be
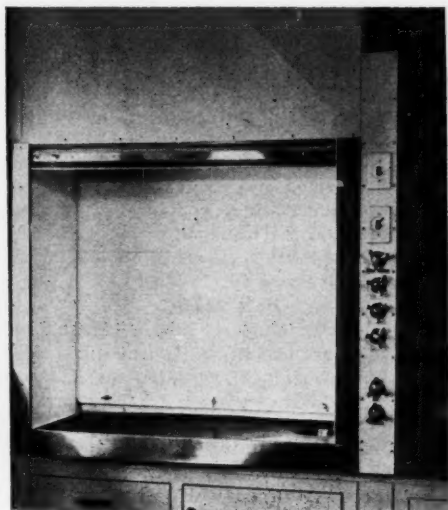
Fig. 8.
Los Alamos Hood A.
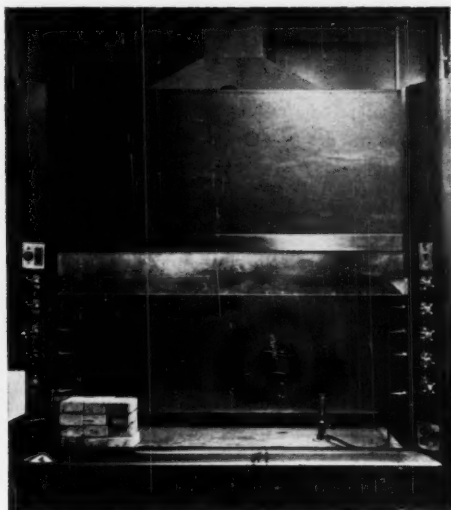
Fig. 9.
Los Alamos Hood B.
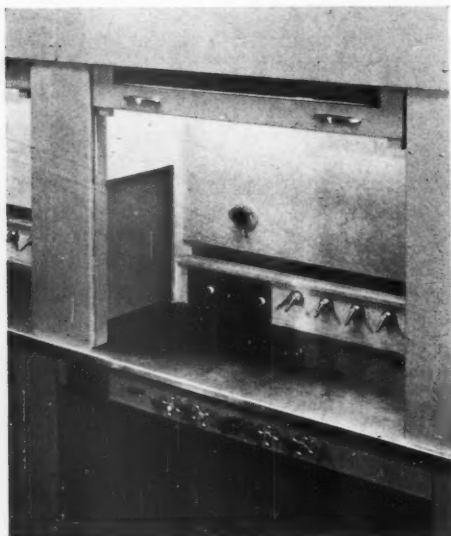
Fig. 10.
Los Alamos Hood C.

Fig. 11.
Los Alamos Hood D.

connected to overhead ducts, the location and design of the top slot should insure that dropping particles or droplets will not fall onto the work surfaces of the hood. While the matter of individual hood filters and washdown sprays behind the hoods was not investigated in this study, the need for such equipment should be considered carefully when the system is being designed.[13,14]

Utility Connections—The number and variety of utility outlets within the hoods apparently are increasing. The latest Los Alamos hood has a total of 20 outlets for 12 different services. The placement of this number of outlets may create an obstruction sufficient to disrupt the flow pattern. This is especially true if the outlets are placed on the side wall close to the hood face. The mounting of utility connections should be such as to insure ease of access for repair and maintenance.[9,15]

Characteristics of Specific Hoods

HOOD MANUFACTURERS have designed and installed many more types of hoods than can be described in this paper. Therefore, this review will be limited to a number of hood types installed at Los Alamos which illustrate specific hood features.

Los Alamos Hood A (Fig. 8)—This par-

ticular hood is characterized by a sharp edged entrance and a mechanically linked by-pass which exhausts air near the floor. In actual use, these hoods have an average face velocity of 125 to 150 feet per minute. In spite of this high face velocity, the sharp edged entrance visible in the above figure causes back flow and cross drafts will often pull material out from the face of the hood. There is an air flow adjacent to the front half of the side walls and inside the corner post with a velocity of 100 feet per minute toward the hood face.
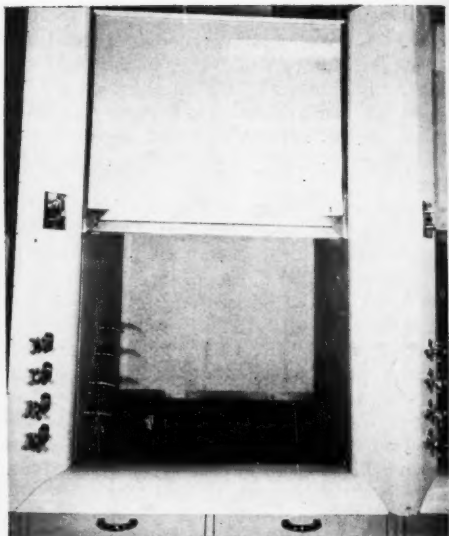
Los Alamos Hood B (Fig. 9)—This hood is characterized by streamlined entrances and is commercially advertised as the Oak Ridge type hood. This hood is very satisfactory under normal operating conditions as long as an average face velocity of 100 feet per minute is maintained.

Los Alamos Hood C (Fig. 10)—This hood has a blower located above the hood and has a by-pass damper actuated mechanically by the door. It also has a lower slot raised six inches above the hood base. Tests on this hood demonstrated the adverse effect of corner posts and the fact that the ordinary unobstructed base was comparable in effectiveness to a base equipped with an air foil.

Los Alamos Hood D (Fig. 11)—This hood is one installed in our own laboratories. It is characterized by streamlined entrances and individual ducts with dampers for both top and bottom slots. It has a gravity-type by-pass at the top of the front of the hood. This hood operates at an average face velocity of 100 feet per minute and has given very satisfactory performance under normal operating conditions. The by-pass does not operate quite as well as anticipated and smoke will escape through the by-pass under heavy thermal loading.

Los Alamos Hood E (Fig. 12)—This hood has a streamlined entrance, no doors and is twelve feet long. This hood was specifically designed for the digestion of urine samples with nitric acid and operates satisfactorily for this purpose.

Los Alamos Hood F (Fig. 13)—This hood is included by reason of the fact that it is one of the most common types found in industry and universities throughout the country. It has no by-pass and showed the same adverse effects of corner posts. However, at an average face velocity of 100 feet per minute, it gives satisfactory performance.

Los Alamos Hood G (Fig. 14)—This hood has a nearly plain entrance and was origin-

Fig. 13.
Los Alamos Hood F.

ally installed with an electronically controlled by-pass. The control for this by-pass consisted of a balanced hot wire located in a small opening on the side of the hood, the air flow through this opening increasing as the hood door was pulled down. As previously mentioned, this control was unstable and was finally disconnected and the control damper locked in position. The hood operates satisfactorily under normal conditions with the doors open.

Conclusions

1. AN AVERAGE face velocity of 100 feet per minute and a minimum velocity of 80 feet per minute at any point on the hood face is necessary for hoods handling substances of moderate toxicity.

2. The hood should be located in the laboratory at such a point as to minimize hazards to personnel in the event of fires or explosions and in so far as possible should be away from the cross drafts, high velocity supplied air inlets and other sources of air disturbance.

3. Normal heat loadings will not adversely effect the performance of a hood with an average face velocity of 100 feet per minute.
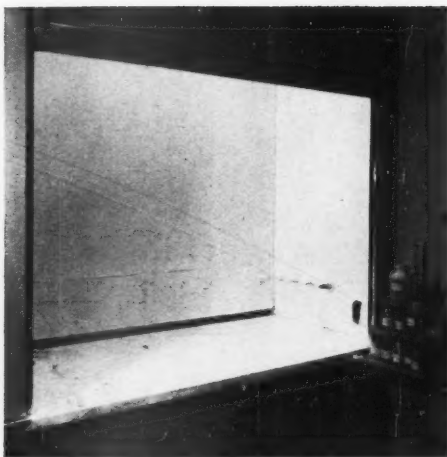

Fig. 12.
Los Alamos Hood E.

Fig. 14.
Los Alamos Hood G.

Hoods with very high heat loads should have the major portion of the air exhausted through the top slot.

4. The hood entrance should be kept free of obstructions and irregularities such as corner posts, sinks and excessively depressed bases. A slight improvement in the air pattern is obtained by use of air foils.

5. A hood door does not contribute to the performance of a hood but may be desirable for protection in case of a spill or an explosion. When doors are used, a mechanically operated by-pass of proper design is desirable to keep the face velocity below 300 feet per minute when the sash is closed to a six inch opening and to provide a constant room exhaust rate.

6. Provision should be made for adjustment of the relative quantities of air drawn through the top and bottom slots. This adjustment is best done by means of dampers located outside the hood and not readily accessible to the user.

7. Hood blowers should be located at the discharge end of the exhaust system to maintain a negative pressure in the conveying duct.

8. Utility connections for hoods should be installed in such a manner to insure maximum access for repair and maintenance and minimum interference with air flow near the face of the hood.

9. Conservation of heated or conditioned air can only be obtained by minimizing the size of the hood opening rather than attempting to introduce unheated air at the hood face or reducing the face velocity.

Bibliography

1. *Industrial Ventilation*, pp. 5-55, Lithoprinted Edwards Brothers, Inc., Ann Arbor, Michigan, 1951.

2. *Heating, Ventilating and Air Conditioning Guide*, p. 985, American Society of Heating and Ventilating Engineers, 1953.

3. *What We Make*, Catalog No. 500-1, 2nd ed., p. 174, B. F. Sturtevant Company, Division of Westinghouse Electric, Hyde Park, Boston, Mass.

4. J. F. TURNER: New Laboratory Fume Hoods Cut Air Conditioning Load. *Heating, Piping and Air Cond.*, 23: 113-6, 1951.

5. Laboratory Design for Handling Radioactive Materials. Research Conference Report No. 3, conducted by Building Research Advisory Board, Washington, D.C., 1952.

6. C. G. DETWILER: A Performance Study of Laboratory Fume Hoods. Knolls Atomic Power Laboratory Report No. 864 (January) 1954.

7. S. H. WEBSTER, E. J. LILJEGREN and C. C. POWELL: Hood for Radioactivity Work. *Nucleonics*, 10: 65, 1952.

8. A. D. MACKINTOSH: The Radiochemical Laboratory—An Architectural Approach to its Design. *Nucleonics*, 5: 48 (November) 1949.

9. C. HAINES: Planning the Scientific Laboratory. *Arch. Record*, 108: 107-23, 1950.

10. H. S. COLEMAN, editor: *Laboratory Design*, pp. 61-68, Reinhold Pub. Corp., New York, 1951.

11. H. B. CLAY: Controlling Fume Hood Exhaust in Atomic Energy Laboratories. *Heating, Piping and Air Cond.*, 22: 78, 1950.

12. J. R. BRADFORD: *Radioisotopes in Industry*, Reinhold Publishing Co., New York, 1953.

13. W. B. SOBERS: Perchloric Acid—It Can Be Used Safely. *Foundry*, 8: 95, 1952.

14. L. E. PREUSS and J. H. WATSON: Design and Construction of a Small Radioactivity Laboratory. *Nucleonics*, 5: 11, 1950.

15. C. N. SJOGREN and J. M. DEAL: Design and Construction of Petroleum Refining Laboratory. *Ind. and Eng. Chem.*, 41: 1667, 1949.

16. A. K. SOLOMON and C A. FOSTER: A Hood for Work with Radioactive Isotopes. *Anal Chem.*, 21: 304-6, 1949.

17. R. E. HOLMES: Ventilation of an Atomic Energy Laboratory. *Refrig. Eng.*, 59: 755-759, 1951.

Toxicological Data—Sources of
Information and Future Needs

HENRY F. SMYTH, JR., Ph.D., Mellon Institute, Pittsburgh

THE SIMPLEST statement about toxicology is that a poison is too much. Any substance is injurious when the intake exceeds some particular amount. Any substance can be tolerated in some particular daily intake, with the possible exception of beryllium, the action of which is not yet fully understood.

It is helpful to have definite quantities to think about. The generally accepted tolerable amounts of some air-borne materials can be expressed in terms of the total weight having no effect when inhaled during an eight-hour period every day, by using the rough figure of ten cubic meters as the volume of air inhaled in a working day. A few values will be illustrative.[1]

Soluble uranium	0.5 mg.
Mercury, cadmium, parathion	1.0 mg.
Lead	1.5 mg.
Arsenic	5 mg.
Fluoride	25 mg.
Nitrobenzene	50 mg.
Carbon disulfide	620 mg.
Benzene	1100 mg.
Carbon tetrachloride	1560 mg.
Acetone	2400 mg.

One-half hour of breathing 22,000 PPM of carbon tetrachloride will produce deep narcosis with a possible fatal outcome.[2] This datum of concentration and time represents 87 gm. or about two fluid ounces of the solvent in the inhaled air. The 1560 milligrams of carbon tetrachloride which is listed above as tolerable for daily inhalation totals 375 gm. in a year, over a pint. It represents 200,000,000 molecules for every body cell every working day.[3]

One and one-half milligrams of lead a day in the inhaled air can be tolerated, as can 1½ gm. of carbon tetrachloride. Thus it may be said that lead is 1000 times as toxic as carbon tetrachloride. But it would be misleading to say that lead in an industrial

operation is 1000 times as dangerous as carbon tetrachloride. Lead compounds are dense solids and carbon tetrachloride is a volatile fluid. Obviously when the two are handled in the same way organic vapors in the air will be more likely than lead dust in the air. This crude example emphasizes the fact that knowledge of the toxicity of a material is not sufficient to protect workmen. We must know also the hazards of the working methods. For clear thinking about industrial hygiene it is important to distinguish between the toxicity of a material and the hazards of an operation with the material. Hazard involves physical properties as well as such factors as amount handled, surface exposed, temperature and frequency of exposure. In many situations toxicity is a less important contributor to danger than are the working methods.

The industrial hygienist feels insecure when a plant which concerns him is using a chemical until he has an authoritative statement of a value known variously as the hygienic standard of inhalation, the threshold limit and the maximum allowable concentration. When he has obtained such a statement his insecurity tends to approach zero. For several reasons this knowledge of the quantitative toxicity of a chemical is only part of the information which is required to use the material safely.

The standard assumes a uniform unvarying concentration throughout the day. Industrial operations almost always create widely varying concentrations with peaks well above the average. With some materials the effect of peaks throughout the day is the same as the effect of the time-weighted average concentration. With others the effect of peaks is greater than the amount they contribute to the day's average. With still others, symptoms of irritation are evident from any briefest concentration above the standard. Tables of standards contain

no reference to such differences between the actions of different chemicals, and indeed for many chemicals the behavior in this respect is not understood.

Reliance on a hygienic standard alone for protection of health requires one of three situations, none of which are frequently encountered. Concentrations must not vary from day to day in order that occasional analyses may give assurance that the standard is never exceeded, or recording instruments with alarm or automatic control features must continuously sample all working points, or an industrial hygiene team must be functioning in the area during all working hours.

Furthermore, a standard assumes that workmen are equally sensitive and that their sensitivity does not vary from time to time with changes in their general health. Neither assumption is true. Without some means to detect the particularly susceptible man we must either tolerate his development of serious injury in a concentration which does not affect his fellows, or we must keep concentrations so low that no individual, no matter how sensitive, can possibly be affected. The first alternative is outrageous and the second unduly restricts working methods and would require uncalled for expenditure for protective equipment.

When knowledge of toxicology is sufficient we will have a clear picture of the subjective symptoms and objective signs to be expected from excessive exposure to a chemical long before irrevocable injury is done. When these facts of qualitative toxicology are available we can overcome the deficiencies of quantitative toxicology outlined above. We have assurance that no permanent injury can occur from unanticipated variations in concentration of air-borne material, from undetected high sensitivity in a particular individual or from possible error in setting the quantitative hygienic standard.

To be fully effective to the industrial hygiene team, including the responsible physician, toxicological data on a chemical should include answers to the following questions:

1. What uniform concentration is tolerable eight hours a day for a working life time?

2. What correction in the average must be made for brief peak concentrations?

3. What single brief exposure to a high concentration is tolerable each day when there is no exposure the rest of the day?

4. What biological test upon the workman can measure his actual intake of the chemical at his job?

5. What are the earliest symptoms and objective signs of excessive exposure, and how severe can they become before removal from exposure fails to prevent permanent injury?

6. What is the best treatment for the effects of excessive single exposure or excessive repeated exposure?

The industrial hygienist himself requires information upon the first three points, but it is necessary for his complete functioning that his medical colleague have information upon the last three points. It is probable that the six points listed cannot be completely and satisfactorily answered for any industrial material although fairly complete answers are available for many.

The most dependable American source for opinions upon the long-time intake of familiar air-borne chemicals is the annually revised list of threshold limits by the American Conference of Governmental Industrial Hygienists released each April and now published in a Fall issue of the A.M.A. *Archives of Industrial Hygiene and Occupational Medicine*.[4] The values are well-considered and they usually represent the consensus of several years widespread experience with each material. Unfortunately, since the publication of Cook's article in 1945,[3] no one has pointed out the scientific basis for each tabulated value to allow assessment of its relative validity. Some are simply extrapolations from animal experiment which are subject to correction as experience accumulates and others are based on many published reports of human experience. Specifically two values from my own animal work, those for isophorone and mesityl oxide, have remained unchanged since the first entry, based solely on my 1942 publication.[6] It would be well if some way could be found to indicate the basis and the relative validity of each of the values tabulated.

For newer and less widely used materials there is no one place to look for hygienic standards. One must search the literature, which is best done through Chemical Ab-

stracts, and one must make tentative estimates from any information found, guided somewhat by structural analogies with better known chemicals. Usually the manufacturer of a new chemical will be able to furnish some basis for tentative estimates and hence such direct inquiry is a sound move.

The most valuable current literature and current abstracts are contained in the A.M.A. *Archives of Industrial Hygiene and Occupational Medicine.*

The most convenient source for concentrations tolerable for brief periods is Henderson and Haggard's "Noxious Gases."[2] Many of the data here go back to animal experiments in Germany during the first quarter of the century but are still sound.

Searches for the qualitative data needed by the physician should be left to those thoroughly familiar with the literature of the medical sciences. The most useful single reference book is Von Oettingen's "Poisoning,"[7] but it leaves something to be desired in its coverage of industrial materials.

Several organizations publish leaflets on single chemicals, each summarizing what is known about the toxicology and safe handling of materials. All are quite limited in number of materials covered and are brief, but some list literature references for more details. Among these organizations are the Manufacturing Chemists' Association[8] and the American Petroleum Institute.[9]

A few groups have attempted to set themselves up as clearinghouses for unpublished toxicological results of interest to the industrial hygienist but various factors have prevented useful coverage of the field.

Experimental toxicological study is now the general practice of makers of chemicals. More and more new chemicals are studied by screening methods before any amount is sold. Since 1944[10] the term "range-finding" is receiving acceptance to describe this preliminary screening. As it becomes certain that a chemical will be a regular item of commerce more advanced work is performed. The studies of Irish and his group on chlorinated hydrocarbons[11] may be considered a pattern for advanced work.

Despite an infinite amount of animal work upon a new chemical the tolerable human intake will remain only tentatively defined until human observations have been made.

A pressing need is for the publication of workroom analyses and clinical examination of the workmen in order to validate more fully or to correct the commonly used hygienic standards for inhalation. At present most detected human injuries are likely to be reported in the literature but instances where no injury results are not published. It is understandable that authors hesitate to write, and editors hesitate to accept, articles which simply reassure. The sensational is more attractive, but we badly need more studies like that of Sterner *et al.*[12] on butyl alcohol where air concentrations were followed for 10 years and clinical studies of the workmen involved showed no injuries. We are neglecting our duty if we do not collect and publish such data. Toxicologists properly discharge their duty to use animals to establish probable safety before human use begins, but after a material is an article of commerce we rely too much on rare accidents to authenticate or to correct the animal predictions. Many files are loaded with pertinent data. How can it be dragged out and published?

References

1. Calculated from values in (4).
2. HENDERSON, Y., and HAGGARD, H. W.: Noxious Gases, Reinhold Publishing Company, New York, Second Edition, 1943, p. 201.
3. CLARK, A. J.: The Mode of Action of Drugs on Cells, Edw. Arnold Company, London, 1933. Quoting Parker, 1930, estimates the number of cells in the body of a 70 kilo man as 26×10^{12}.
4. Threshold Limits for 1953: *A.M.A. Arch. Indust. Hyg. & Occup. Med.*, 8, 296-298, 1953.
5. COOK, W. A.: *Indust. Med.*, 14, 936-946, 1945.
6. SMYTH, H. F., JR., SEATON, J., and FISCHER, L.: *J. Indust. Hyg. & Tox.*, 24, 46-50, 1942.
7. VON OETTINGEN, W. F.: Poisoning, Paul B. Hoeber, New York, 1952.
8. Manufacturing Chemists' Association, 246 Woodward Bldg., 15th & H Sts., N.W., Washington 5, D.C. Fifty-four Chemical Safety Data Sheets to date.
9. American Petroleum Institute, 50 W. 50th St., New York 20, N.Y. Sixty-three Toxicological Reviews to date.
10. SMYTH, H. F., JR., and CARPENTER, C. P.: *J. Indust. Hyg. & Tox.*, 26, 296-273, 1944.
11. ADAMS, E. M., SPENCER, H. C., ROWE, V. K., McCOLLISTER, D. D., and IRISH, D. D.: *Arch. Ind. Hyg. & Occup. Med.*, 6, 50-66, 1952. SPENCER, H. C., ROWE, V. K., ADAMS, E. M., McCOLLISTER, D. D., and IRISH, D. D.: *Arch. Ind. Hyg. & Occup. Med.*, 4, 482-493, 1951. ADAMS, E. M., SPENCER, H. C., ROWE, V. K., McCOLLISTER, D. D., and IRISH, D. D.: *Arch. Ind. Hyg. & Occup. Med.*, 4, 469-481, 1951. ROWE, V. K., McCOLLISTER, D. D., SPENCER, H. D., ADAMS, E. M., and IRISH, D. D.: *Arch. Ind. Hyg. & Occup. Med.*, 5, 566-579, 1952. McCOLLISTER, D. D., BEAMER, W. H., ATCHISON, G. J., and SPENCER, H. C.: *J. Pharmacol. & Exper. Therap.*, 102, 112-124, 1951.
12. STERNER, J. H., CROUCH, H. C., BROCKMYRE, H. F., and CUSACK, H.: *Am. Indust. Hyg. Assoc. Quart.*, 10, 53-59, 1949.

Preparing Dust Samples for Microscopic Examination—Notes on a New Method

C. D. YAFFE, M.S., H. J. PAULUS, Ph.D., and H. H. JONES, B.S.

Occupational Health Field Headquarters, Division of Special Health Services

U.S. Public Health Service

Cincinnati

WHEN SAMPLES of airborne dust are collected for the purpose of counting or sizing, one of two general approaches is customarily followed. In one instance, the dust from a relatively small volume of air is deposited by one means or another directly upon a slide which may then be subjected to direct microscopic examination. This general principle is the one employed in the use of such instruments as the thermal precipitator, cascade impactor, and konimeter. Each of the instruments using this principle has certain virtues and defects. However, they all have in common one disadvantage: the total number of particles collected must be limited so that there will not be an excessively heavy deposition. If this occurs, the number becomes too great to count; and in the event that the particles pile up, it may not be practicable even to determine size accurately. Consequently, the volume of air which may be sampled normally must be limited to a few cubic centimeters or liters.

Where it is desired to sample larger volumes of air, the second approach is employed. In this case, sampling is carried out for a suitable period, and the dust is trapped in some type of collector such as an impinger, filter, or electrostatic precipitator. The dust is then suspended in a definite volume of liquid and an aliquot examined under the microscope.

While this approach permits the sampling of any desired volume of air, there are admittedly certain defects encountered in counting dust suspended in a liquid. Solution of even such relatively insoluble materials as silica may have an influence on the results. The length of settling time is definitely important, and inconsistent results may occur due to differences in particle size or density of materials involved.

Recognizing the drawbacks to the various techniques and procedures which have been in common use for many years, the Engineering Section of the Division of Occupational Health has for some time been subjecting these various methods to a very critical review and appraisal to determine whether they are satisfactory for present-day needs, and, if possible, to develop new or improved procedures which more nearly meet the desired specifications.

In considering the first of the two general approaches which have been mentioned, it is readily apparent that when the dust is collected in this fashion, the sample may be retained indefinitely providing a permanent record which may be re-examined when desired. Samples examined in a liquid suspension, on the other hand, cannot be kept in this way. If some satisfactory method could be found whereby the aliquot for microscopic examination could be put into a fixed form, that is, mounted dry, it would enable us to combine some of the more desirable features of the two general principles which have been outlined above. To accomplish this, however, presents some difficulties. If a drop of liquid containing a dust suspension is allowed to evaporate to dryness, the dust which had been suspended is not deposited uniformly but is concentrated, usually in a series of concentric rings. The problem, therefore, is how to obtain instantaneous evaporation of the liquid from a uniform suspension of dust so that the particles are "frozen" in their original random positions. Several attempts to solve this problem proved unsuccessful.

One of the newest and most promising in-

struments for dust sampling is the molecular, membrane, or Millipore* filter. Many industrial hygiene laboratories have been studying its potentialities, and its possible use for dust sampling has been described by First and Silverman.[1] This filter possesses several quite desirable features. It may be used with a simple holder. It samples at very high efficiency over a wide range of air flows, and the samples may be examined directly with the microscope. If a drop of immersion oil of the proper refractive index is employed, the filter becomes transparent under the microscope, leaving only the dust particles visible.

If samples collected with the molecular filter are to be subjected to direct microscopic examination, the usual limitation on the total number of particles which can be collected still applies. While no exact limit can be set, simple computations will show that in any fairly dusty situation the total volume of air which can be sampled probably must be limited to something less than one liter.

However, as Silverman and First point out, if the number of particles collected is too great for direct count, the filter may be dissolved in a suitable solvent, such as acetone, and an aliquot of the suspension of dust examined, using the technique normally employed for impinger samples. This adds greatly to the utility of the molecular filter for dust sampling purposes.

The technique of direct microscopic examination of molecular filter samples is much simpler and more satisfactory than the examination of the dissolved material. In view of this and recalling the earlier attempts to produce satisfactory dry mounts of impinger samples, we wondered if it might be possible to take an aliquot of a dissolved molecular filter sample and reconvert it into a dry form. Allowing a drop of the dissolved material to evaporate on a slide resulted in the concentration of the suspended dust into the usual series of concentric rings. The thought occurred, however, that the reconversion to solid form might be speeded up considerably by a sudden increase in the concentration of the cellulose ester of which the molecular filter is made. This was accomplished by bringing the drop of dissolved filter in contact with

*Trade Name.

another piece of clean molecular filter. The result was quite surprising. The filter absorbed the liquid with extreme rapidity and the dust did "freeze" in a random disperse pattern on the filter. At the point where this reaction took place, the character of the filter was radically changed. It became entirely colorless and transparent and tough, like Cellophane,® in contrast to its original form, which is white, opaque, and brittle. The spot at which the reaction occurred could be examined directly with the microscope without the use of any immersion oil. If the reaction is performed on a slide, the tough transparent film which is formed is firmly attached to the slide. The net results in some respects, therefore, were better than had been either hoped for or anticipated. If a satisfactory technique could be developed, large volumes of air could be sampled, the filter dissolved, and a suitable portion then mounted on a slide in a dry, permanent form ready for direct microscopic examination.

Perhaps the principal problem associated with this proposed procedure is the necessity of using a small volume of the liquid suspension and "reprecipitating" the material in a relatively small measurable area.

(The term "reprecipitating" is employed here in a qualified way as we are not certain yet exactly what the nature of the reaction is when the solution of filter is brought into contact with an additional portion of dry filter. Our first assumption was that the involved area of filter dissolved and then immediately reprecipitated. It has been observed, however, that if a piece of molecular filter is dropped into acetone and not agitated, the filter immediately becomes transparent but retains its shape and does not dissolve for an appreciable period, a gel apparently being formed.)

The small liquid volume is necessary in order that the number of particles and the area to be examined may be suitable; furthermore, if too much of the liquid is concentrated on the filter, a hole is produced. Preliminary experiments indicated that the largest practicable volume of liquid was probably somewhat less than 0.1 ml. Because of the necessity of using such a small aliquot, it is recognized that a considerable error in the final results may be introduced unless that volume can be measured with

accuracy. This would probably require the use of a suitable micropipette or syringe and considerable care in technique. Following the trial of several devices which were relatively unsatisfactory, we came across the 0.01 ml. syringe used for bacterial count determination by direct microscopic method as described in "Standard Methods for Examination of Dairy Products" issued by the American Public Health Association.[2] This syringe is used for the rapid transfer of 0.01 ml. milk or cream and is equipped with a semi-automatic spring-actuated plunger. The volume discharged by the syringe is automatically regulated; and according to the manufacturer's claims and additional information supplied by individuals who have tested it, it is accurate within plus or minus 0.0005 g. or 5%. Certification of the instrument's accuracy may be obtained. Such certification is mandatory in some localities for testing of milk and cream.

Through the use of this syringe, it was found that if 0.01 ml. of acetone suspension (a $1\frac{1}{4}$-inch circular disc of molecular filter dissolved in 100 ml. acetone) is applied to a dry molecular filter, the subsequent reaction takes place over an area equal approximately to a quarter-inch diameter circle. This is a quite satisfactory area for the purpose of microscopic examination.

While the transparent area in which the dust is thus fixed may be measured even though of irregular shape, it would be simpler and more desirable if that area could be controlled and made the same each time. Various methods for accomplishing this have been and are being explored. One method is to drill a $\frac{1}{4}$-inch hole in a microscope slide, cover it with a slightly larger piece of molecular filter and place the liquid on it. The transparent film forms across the hole. Instead of using glass slides which break easily, particularly if more than one hole is desired in each, metal slides may be used.

Fig. 1 shows a glass slide with the filter mounted in two holes. The one on the left is untreated while the one on the right has a dust sample in it.

Fig. 2 shows an aluminum slide with four $\frac{1}{4}$-inch holes, each containing a molecular filter disc. The discs in the lower holes have been treated with the dust suspension. The clarity of the printing on the paper illustrates how transparent the molecular filter
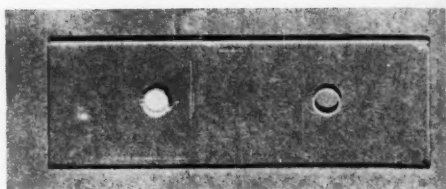
Fig. 1.
Glass slide with molecular filter mounted in two $\frac{1}{4}$-inch holes. The filter on the right contains a sample.

has become. Normally, the metal slides would be made the same size and shape as a glass microscope slide. In this particular case, the slide was made two inches square to fit into a projection device.

Another method which has been employed utilizes the gummed reinforcements that are ordinarily used with loose-leaf notebook paper. These can be obtained with a quarter-inch hole in the center. Circles of molecular filter slightly larger than one-quarter inch diameter but smaller than the outside diameter of the reinforcing ring are cut with a cork borer. (We purchase molecular filter material in sheet form and cut it to the de-
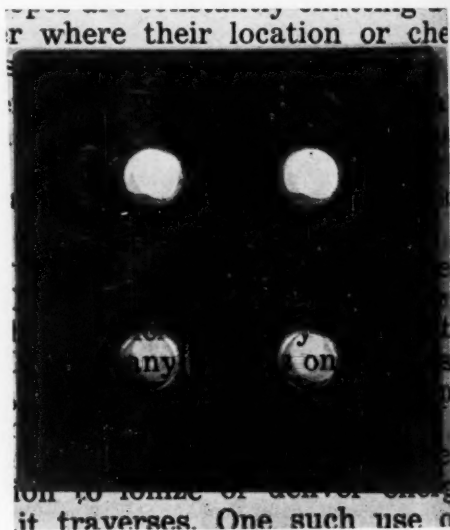
Fig. 2.
Aluminum slide with four $\frac{1}{4}$-inch holes. Transparency of the film containing the sample can be seen in the lower holes. Samples have not been added to the upper holes.
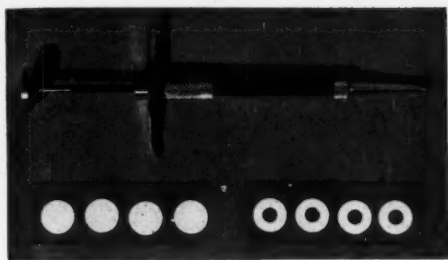
Fig. 3.
This syringe delivers 0.01 ml. of the sample.
The two microscope slides show the molecular
filter discs mounted under reinforcing rings.
Dust samples have been mounted on the slide
on the right.

sired size. This is somewhat less expensive
than purchasing specific sizes. It is neces-
sary, however, to use considerable care in
handling it to avoid waste, as it is rather
tricky to work with, due to its fragility and
electrostatic properties.) The circular disc
of filter is attached to the reinforcing ring
so that the hole is completely closed, and
the ring is immediately fastened to a micro-
scope slide. A number of filters may be
mounted on a single slide. They are then
ready for use. The 0.01 ml. of dust suspen-
sion is placed in the center of the molecular
filter. The reaction is instantaneous and
the slide is ready for immediate microscopic
examination.

Fig. 3 shows the pipette employed for
measuring 0.01 ml. and also two microscope
slides on which molecular filters have been
mounted under reinforcing rings. Dust
samples have been mounted on the slide on
the right. The transparency of the mount is
further indicated in Fig. 4 where the same
slide has been placed on a printed page.

It has not yet been determined whether
any of the dust is carried into that portion of
the molecular filter which is under the edge
of the reinforcing ring. It does not seem to
occur, at least to any significant degree.
Since the circle of filter need be only slight-
ly larger than the hole in the reinforcing
ring, the error, in case this assumption is
erroneous, would be slight in any case.

Where dust counts are to be made, the
same general procedure which is used in the
light field method for impinger samples can
be followed, counting five different fields in
duplicate aliquots.

In some instances when the acetone sus-
pension is applied to the filter, the reaction
may not be too uniform. This is probably
due to the failure of the liquid to spread
rapidly enough over the filter. In such cases,
there is formation of some bubbles and
other irregularities, possibly even holes in
the transparent film which is formed. Seri-
ous difficulty of this type can be avoided,
however, with suitable technique. Also,
other solvents may prove to be more satis-
factory. The majority of mounts have been
found to be usable. To insure that there will
be two satisfactory mounts and since the
technique is so simple and rapid, we are
forestalling any difficulties by preparing 3
or 4 and using the first two satisfactory
ones examined.

Fig. 5 is a photomicrograph of a quartz
dust sample prepared with the procedure
described. It will be noted that the dust is
well distributed in random fashion.

Table I shows the results obtained when

Fig. 4.
Four treated molecular filter discs on a micro-
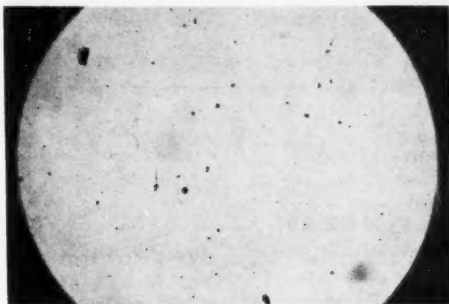scope slide show transparency of the mount.

Fig. 5.
Photomicrograph of a quartz dust sample. This
was taken on a treated molecular filter disc
mounted under a reinforcing ring. Magnifica-
tion is about 200x.

TABLE I.				
Sample No. 1				
Aliquot No.	1	2	3	4	5
	85	42	65	67	50
	57	83	61	55	57
	102	62	83	78	79
	80	76	59	49	76
	90	56	70	56	73
Average	83	64	68	61	67
Sample No. 2				
Aliquot No.	1	2	3	4	5
	82	144	98	125	132
	90	114	151	109	84
	123	99	112	131	110
	118	136	129	142	136
	99	113	96	112	119
Average	102	121	117	124	116

counts were made in five random fields of five aliquots of each of two samples. The range of counts is within the limits usually encountered in other comparable methods.

Considerable additional work will have to be done testing the procedure, improving the technique, and making comparisons with other methods in order to determine whether the method is equal to or superior to others now employed. The simplicity of the technique and the production of a slide which provides a permanent record are features which make the method quite attractive. It is presented here with the thought that other investigators might wish to explore the potentialities which it offers.

References

1. First, M. W. and Silverman, L.: Air Sampling with Membrane Filters. *AMA Arch. of Ind. Hyg. and Occ. Med.*, 7:1, January, 1953.

2. According to "Standard Methods for Examination of Dairy Products," pp. 115, 117—10th Edition, two models of syringe, each based upon a distinctly different volume control mechanism, are available from sources as follows: Riggs and Nisson Jewelers, 913½ Eye Street, Modesto, California; and Applied Research Institute, 2 East 23rd Street, New York 10, New York. One from the latter source was available to the writers and was used in the work described.

Radiological Health Training

THE PUBLIC HEALTH SERVICE, U.S. Department of Health, Education and Welfare, is sponsoring a radiological health training program with the purpose of indoctrinating public health workers with the significance of ionizing radiations, the environmental and occupational hazards attendant on their use, and recommended procedures for minimizing such hazards. The training program is presented at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. It is designed primarily for professional personnel of State and local health departments, but a limited number of qualified applicants from other governmental agencies and industry will be welcome. Further information may be obtained from: Chief, Radiological Health Training Section, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

Absolute Control of Chromic Acid Mist

—INVESTIGATION OF A NEW SURFACE-ACTIVE AGENT

G. HAMA and W. FREDRICK, Sc.D., Detroit Department of Health
D. MILLAGE and H. BROWN, Ph.D., The Udylite Corporation

A N ENTIRELY new type of surface-active agent, ZEROMIST,* containing a fluorocarbon chain which endows the compound with extremely high stability and surface-activity has been developed for the control of chromic acid mist and spray from chromium plating baths. This paper is a report of an investigation made to determine the effectiveness of ZEROMIST in suppressing the mist from chromium plating operations. Chromium plating is in world-wide use for decorative and engineering purposes, due to the superlative properties of chromium plate from the standpoint of tarnish and atmospheric corrosion resistance, its outstanding resistance to heat and wear, and its low coefficient of friction.

The baths for the electrodeposition of chromium consist of rather concentrated solutions of chromic acid (about 150 to 400 gm. per liter of chromic acid anhydride) and contain in addition, definite small percentages of sulfate, fluoride or fluosilicate anions (in a ratio of about 100 parts of CrO_3 to one of sulfate or other "catalyst" anions). Insoluble anodes (lead or lead alloy e.g. Pb-Sn) are used. High cathode current densities are required for the deposition of chromium, about 15 amp./sq. dm. to 30 amp./sq. dm. (approximately 140 to 280 amp./sq. ft.) and even higher current densities are used. The cathode efficiencies vary from about 10 to 20%, and therefore a large volume of hydrogen is liberated during plating, and since insoluble anodes are used, oxygen is evolved at the anodes.

These gases evolved during electrolysis in the form of multitudinous bubbles of high surface tension burst violently at the surface of the concentrated chromic acid solution and throw out a fine mist of chromic

acid droplets. The spray and mist resulting from this bubble bursting is of considerable volume because of the high current densities used in the plating, the low efficiency of chromium deposition and use of insoluble anodes. Due to the corrosiveness and toxicity of chromic acid mist, and its well known deleterious contaminating effect on other plating baths, such as, nickel, copper, cadmium and zinc, it is necessary to employ efficient local exhaust ventilation to continuously remove the mist as it is formed. The quantity of air exhausted can be quite large. For example, to carry away the mist formed in a 2,000 gallon tank installation, an exhaust rate of as much as 10,000 cubic feet per minute may be required.[1,2,3]

In some cases, it is difficult to attain good control of the mist by ventilation alone. This is especially true on wide tanks and in locations of strong cross-drafts. Also, slots and ducts on chromium plating ventilation systems become coated and may sometimes plug because of the high concentrations of mist in the exhausted air. The maintenance costs on these systems are high because of coating and corroding of the hoods, ducts and fans.

The loss of chromic acid through mist and spray amounts to approximately 30% of the total chromic acid used.[4] This chromic acid mist is discharged through the exhaust stack and may create an outdoor air pollution problem which requires correction with expensive air-washing equipment. The amount of chromic acid exhausted together with that which is carried out on the surface of the articles, actually represents considerably more chromic acid than that which is used in the formation of the chromium coating.

The health hazards, air pollution problems, and waste of chromic acid resulting from the formation of chromic acid spray

and mist in commercial chromium plating were recognized from the very inception of chromium plating, and various attempts were made to prevent or to greatly minimize the formation of this spray and mist. As examples of attempted solutions of the problem of preventing or minimizing the spray and mist, it has been suggested to form blankets on the surface of the bath by using various saturated oils such as paraffin oils or hydrocarbons similar to kerosene. The use of such materials and the problems involved has been reviewed by Alter and Mathers.[5] The inconveniences caused by an oil layer on the surface, its carry-over into rinse waters, possible fire hazards, and possible dermatitis effects from the oil itself, have greatly limited the use of such oil blankets. The use of foaming or frothing agents such as cresylic acid, saponin, etc., though effective with many electrolytic baths are of little value in the chromium plating baths using concentrated chromic acid, and are rapidly oxidized. Fish oils[5] which can be used in much smaller concentration than mineral oils because of their tendency to give foam blankets on the surface of the chromium baths, are more stable than cresylic acids or saponin, and have been more successful, but because they are also oxidized away rather rapidly, requiring frequent or continuous additions, they have never been extensively used.

Floating objects such as paraffin-dipped corks or glass wool were also tried quite early[5] as blankets and more recently plastic beads, chips and rods have been tried.[6,7,8] However, while blankets of these materials on the surface help to decrease the mist and spray, their use is generally confined to "hard" chromium plating where relatively thick chromium is deposited for engineering purposes, and the parts to be plated are left for hours in the plating tank. Thus, the plastic beads can be spread as a heavy blanket over the surface of the bath and left undisturbed during the long plating time. However, in decorative or bright chromium plating, the plating time is usually around five minutes or less and it is too difficult to keep the layer of plastic beads distributed properly over the surface with the very frequent entry and removal of plating racks. Thus, the use of layers of plastic beads, while of little or no value in

decorative or bright chromium plating, has attained a limited but helpful use in "hard" chromium plating. However, no decrease in ventilation is recommended[8] with the use of these beads in chromium plating.

Recently certain specialized classes of regular surface-active agents have attained fairly wide-spread use in chromium plating baths, and these surface-active agents are superior to the older foaming agents such as the fish oils of Alter and Mathers. These surface-active agents lower the surface tension of the chromium plating bath and foam blankets can be formed on the surface of the bath during plating. However, those which have been used up to now are also rather rapidly oxidized away at the insoluble anodes as well as by the chromic acid itself and careful control of the concentration of the surface-active agent must be maintained to keep the mist continuously suppressed.[15]

Thus, while it has been recognized for a long time that low surface tension and a foam blanket produced by a surface-active agent would greatly help in preventing or minimizing the spray and mist from chromium plating baths, nevertheless, until re-

TABLE I.

CONCENTRATION OF CHROMIC ACID MIST OVER CHROMIUM PLATING BATHS CONTAINING SURFACE-ACTIVE AGENT

Locations and Conditions:	Conc. CrO₃ (in mg. per cubic meter of air)
Plant A. Chromium plating tank, 1.7 ft. x 4.2 ft. surface area. Hand plating. Fourteen samples taken from breathing zone in aisle to 1 ft. over surface of bath. Ventilation off. Plating current 460 amps.	$0.005\text{-}0.022$
Plant B. Tank 4 ft. x 7 ft. Production plating of automobile parts. Six samples taken in breathing zone of worker. Ventilation off. 9,000 amps. for 0.5 min. and 8,000 amps. for 2.5 min.	$0.002\text{-}0.060$
Plant B. Tank 7 ft. x 7 ft. Production plating of bumper-guards. Six samples taken in breathing zone. Ventilation off. 20,000 amps. for 0.5 min. and 10,000 amps. for 2.5 min.	$0.002\text{-}0.009$
Plant B. Tank 7 ft. x 7 ft. Production plating of bumper-guards. Five samples taken in breathing zone. Ventilation off. Plating current 12,000 to 18,000 amps.	$0.002\text{-}0.014$
Plant C. Tank 2 ft. x 6 ft. Production plating of automobile ornaments. Five samples taken in breathing zone. Ventilation off. 1,200 amps.	$0.002\text{-}0.027$
Plant D. Tank 2 ft. x 3.5 ft. Hand plating of automobile parts. Two samples taken in breathing zone. Ventilation rate 90 cu. ft. per min. per sq. ft. (Required ventilation as standard, 175 cu. ft. per min. per sq. ft. of bath surface.)	$0.000\text{-}0.002$

cently no surface-active agent has been found which could resist the powerful anodic oxidation occurring during chromium plating.

It has now been found that certain new surface-active agents can be made in which the usual hydrocarbon chain is replaced by a fluorocarbon chain, and these fluorinated surface-active agents have been found to be completely stable to boiling concentrated chromic acid and to the highest oxidizing conditions existing at the anodes during chromium plating. "Zeromist" is an example of a class of fluorinated surface-active agents that is completely stable in chromium plating baths. Due to the low surface tension values obtainable and also because of the film stability existing in the bubbles which constitute the thin foam blankets on the surface of the baths, the spray and mist is reduced to very low values. (See Table I and Fig. 1. See also Figs. 2, 3 and 4.)

Fig. 2 shows a chromium plating tank with no foam blanket.

Fig. 3 shows the same tank with the work submerged in the solution during the plating operation. It is to be noted that the foam formed during electrolysis covers the entire surface including the area around the electrodes. It should also be noted that

Fig. 2.
Chromium plating tank with no foam on the surface.

Fig. 3.
Chromium plating tank with work submerged and plating proceeding with formation of the thin foam blanket.

Fig. 1.
Effect of surface-active agent concentration on the reduction of chromic acid mist in discharge duct. Ventilation rate at 100 cfm/sq. ft. of surface area of plating bath. Curve (a) for plating bath temp. of 55°C (131°F). Curve (b) for bath temp. of 38°C (100°F). Plating current at 50 amps./sq. ft. of surface area of bath.
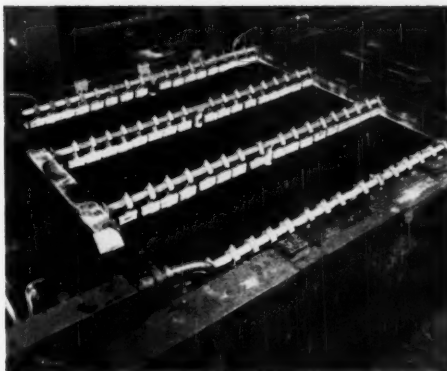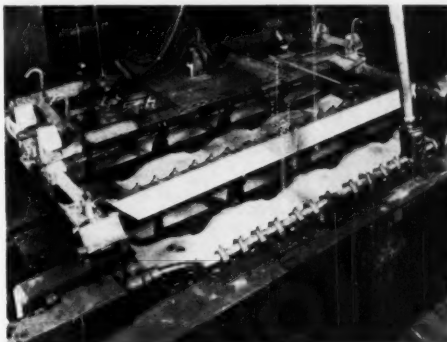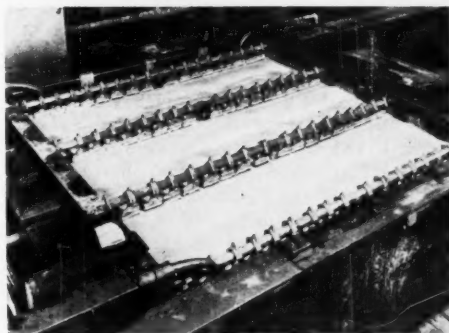

Fig. 4.
Chromium plating tank with plated work just removed. Foam blanket is still present but subsiding rapidly.

the foam blanket is not too heavy. A heavy, thick foam blanket may cause a hydrogen explosion.

Fig. 4 shows the chromium plating solution after the plated work has just been removed. The thin foam blanket formed by the surface-active agent is still present but is in the process of subsiding.

The control of "Zeromist" is simply done by surface tension measurement which is a measure of the concentration of the surface-active agent in the bath (Fig. 5). "Zeromist" is lost only by "drag-out" (in the film of solution on plated articles withdrawn from the bath) and only infrequent additions to compensate for such losses have to be made. Maintenance additions are usually needed not oftener than once per week or less, and usually only about 1/10 the original concentration need be added. Thus, because of the extreme stability of "Zeromist" it is possible to keep the spray and mist continuously suppressed without constant supervision of the status of the concentration of the surface-active agent in the bath.

Since the viscosity of the bubble film varies with temperature, the optimum concentration of surface-active agent for the highest degree of suppression of mist varies with the temperature of the bath (Fig. 6). At lower bath temperatures lower concentrations of surface-active agent can be used to produce a high degree of mist suppression.

To determine the effectiveness of "Zeromist" in suppressing the mist in bright chromium plating operations, a number of work-room air determinations for chromic acid were made in several industrial plants during the regular production plating operations. Breathing zone samples were taken with midget impingers. These samples were taken to the laboratory and analyzed by the Diphenylcarbazide Method. Table I shows the results of the work-room air determinations. In Plants designated A, B and C, the ventilation was turned off during the sampling period. In Plant B, the tank was ventilated at the rate of 90 cfm per square foot of tank area. The ventilation rate required on this tank by the American Standards Association method for calculating air-flow for plating tanks is 175 cfm per square foot of tank area.[9] It is to be noted that the
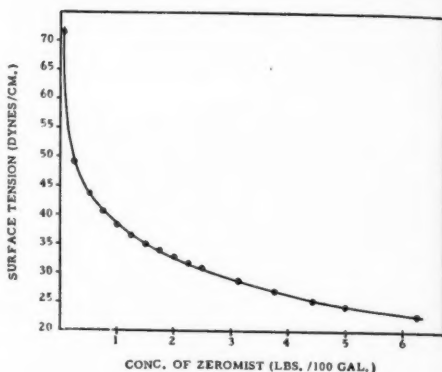
Fig. 5.

Variation of surface tension of chromium plating solution with concentration of surface-active agent, "Zeromist," at temp. of 30°C.
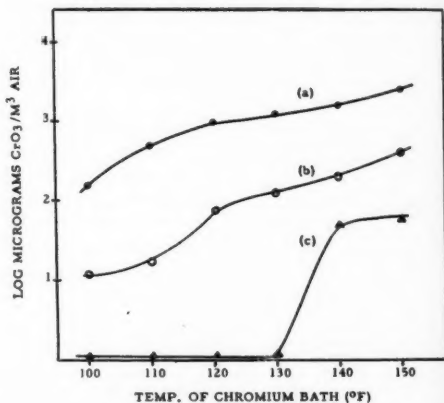
Fig. 6.

Effect of temperature of bath on concentration of chromic acid mist in the discharge duct. Ventilation rate at 100 cfm/sq. ft. of surface area of bath. Current at 10 amps./sq. ft. of surface area of bath. Curve (a) represents bath surface tension at 50 dynes/cm., and curve (b) at 35 dynes/cm., and curve (c) at 25 dynes/cm.

average concentration is considerably below the maximum allowable concentration which is 0.1 mg. chromic acid anhydride (CrO_3) per cubic meter of air.[10]

Stack determinations were made to determine the effectiveness of "Zeromist" in reducing air pollution from discharge stacks on systems ventilating bright chromium plating tanks. These determinations were made by drilling a hole in the discharge stacks and using a glass sampling

probe. The samples were collected in a midget impinger and were analyzed by the Diphenylcarbazide Method.[11]

Table II shows the chromic acid content of stack discharge samples taken in three different plants. The rates of air flow with the ventilation systems on the plating tanks ranged from 90 to 150 cfm per square foot of tank surface area. It is to be noted that there is very little chromic acid in the discharged air.

TABLE II.
SAMPLES TAKEN IN DISCHARGE STACKS OF
VENTILATION SYSTEMS OF CHROMIUM
PLATING BATHS CONTAINING
SURFACE-ACTIVE AGENT

Location and Conditions:	Conc. CrO_3 (in mg. per cubic meter of air)
Plant B. Tank 4 ft. x 7 ft. Production plating. Ventilation by slot exhaust, 150 cu. ft. per min. per sq. ft. of tank area. Plating current 9,000 amps. Two samples taken.	0.009-0.014
Plant D. Tank 2 ft. x 3.5 ft. Slot exhaust, 90 cu. ft. per min. per sq. ft. One sample taken during plating.	0.000
Plant E. Tank 7 ft. x 7.5 ft. Automatic plating of automobile parts. Ventilation rate, slot exhaust, 120 cu. ft. per min. per sq. ft. of tank surface. Temp. of bath 115° F. Plating current 4,200 amps. at 12 volts.	0.01-0.02

There are other contaminants besides chromic acid that might be discharged from chromium plating tanks. Hydrogen is important because of the possible explosion hazard. The thin foam blanket formed by "Zeromist" however, does not retain large quantities of hydrogen. Several determinations were made to determine the concentration of hydrogen directly on the surface of the foam blanket.

Table III shows the results of these determinations. The results are expressed in percent lower explosive limit of hydrogen gas. The determinations were made with a combustible gas indicator.

There appears to be an odor coming from unventilated chromium tanks similar to ozone, and therefore it was decided to check the concentration of ozone coming from the unventilated chromium tanks. These determinations were made by sampling with a fritted glass bubbler. The samples were analyzed by the Alkaline Potassium Iodide Method of Smith and Diamond.[12] Results are given in Table III.

TABLE III.
SAMPLES TAKEN FOR HYDROGEN AND FOR OZONE
OVER CHROMIUM PLATING TANKS CONTAINING
SURFACE-ACTIVE AGENT

Hydrogen Determination	Hydrogen Conc.
Plant G. Tank 1.5 x 2 ft. surface area. Hand plating of small parts. Ventilation off. Current density 150 amps. per sq. ft. Hydrogen determinations made with combustible gas indicator. Four measurements were made just above the surface of the tank over the cathode.	3 to 8% of lower explosive limit
Ozone Determination	**Ozone Conc.**
Plant B. Case 1. Samples taken directly over the anodes at the edge of the tank. Tank 7 ft. x 7 ft. Production plating of bumper-guards. Current 12,000 amps. Ventilation off.	0.013 PPM
Case 2. Samples taken in breathing zone level with same tank and conditions as in Case 1.	0.008 PPM

In chromium plating baths containing fluorides the question of the concentration of hydrofluoric acid in the air above the tanks must be considered. At this time no systematic measurements were made on this, although on one unventilated chromium plating tank (19 in. x 20 in. surface) operating at a temperature of 115° F the concentration of fluoride at the surface expressed as hydrogen fluoride was 3 to 4 parts per million. This tank contained "Zeromist," but not at optimum concentration, therefore it was not determined what percentage was coming off in gaseous form and what percentage in mist form (the mist was quite low, however). The method of analysis for the fluoride in the air was as follows: samples were collected in a fritted glass bubbler, and analyzed by the Zirconium Alizarin Method following a Willard and Winter distillation.[13]

The possibility of the formation of stibine during the chromium plating of an antimony plated surface was also considered. Determinations for stibine were made directly over the plating tank by sampling with a fritted glass bubbler. The samples were analyzed by the Rhodamine B Method of Fredrick.[14] The first sample was taken during the fifteen minute interval immediately after submerging the antimony plated part to be chromium plated. The second sample was taken in the 15 minute interval following the first sample and the third sample was taken 30 minutes after the first sample. The results of these determinations

are given in Table IV. From these results it is to be noted that a small quantity of stibine is formed only during the initial period of plating when the antimony surface is exposed to the hydrogen that is being deposited along with the chromium plate. After the surface is covered with the chromium plate, there is only slight if any possibility for stibine formation.

TABLE IV.
SAMPLES TAKEN FOR STIBINE FORMATION DURING CHROMIUM PLATING OF AN ANTIMONY SURFACE

Location and Conditions:	Conc. Stibine
1. Plant F. Chromium plating of an antimony-plated steel bumper-guard. Sample taken 1 ft. above tank immediately after submerging part in the chromium plating tank and applying current. Ventilation off.	0.3 PPM
2. Fifteen minutes later	Trace
3. Thirty minutes later	None found

Still another troublesome problem connected with chromium plating is the rather frequent dermatitis occurring with workers handling poorly rinsed chromium plated articles. Contact with chromic acid should be reduced with the use of low surface tension baths due to the rapid and more complete run-off of the chromium plating solution, leaving less chromic acid to be rinsed away. Also, the work rack hooks would not be covered with a chromic acid film due to the absence of spray from such baths.

Summary

AIR SAMPLING determinations made on commercially operating bright chromium plating baths containing a new fluorinated surface-active agent "Zeromist," indicate that the concentration of chromic acid mist above the plating solution is reduced to a very low level. Because of the extreme stability of this fluorinated compound, the maintenance of proper concentration in the bath is simple and requires little supervision. Furthermore, with baths of low surface tension there is rapid and more complete run-off of the chromic acid solution from the plated articles on removal from the bath which results in decreased chromic acid drag-out and decreased pollution of the rinse water.

Thus, its important contributions are:
(1) reduced air pollution of the work room;
(2) reduced atmospheric pollution from discharge stacks; (3) reduced losses of chromic acid both from suppression of mist and decreased drag-out loss; (4) decreased pollution of rinse water and decreased staining of the plated articles; (5) reduced incidence of dermatitis caused by excessive carry out of chromic acid on the plated articles. In the cases tested, it appeared that reduced ventilation rates could be used, and that air washing equipment for the exhaust discharge into the atmosphere could be eliminated. On wide tanks which are difficult to ventilate properly or where strong cross-drafts are present, the use of the surface-active agent is invaluable. In general, "Zeromist" should be used to assist or supplement local exhaust ventilation rather than to replace it. Less maintenance would be required on hoods, duct work and fans.

Acknowledgement

References

1. BLOOMFIELD, J. J., and BLUM, W.: U.S. Public Health Rpts. 43, 2330-2351 (September 7, 1928).
2. RILEY, E. C., and GOLDMAN, F. H.: U.S. Public Health Rpts. 52, 172-174 (1937), Reprint No. 1801.
3. SCHWARTZ, L.: U.S. Public Health Service, Pub. Health Bull. No. 299, 80 pp. (1936), Pub. Health Bull. No. 249, 93 pp. (1939).
4. HARING, H. E., and BARROW, W. P.: Tech. Paper Bureau of Standards, No. 346 (January 10, 1927) (part of Vol. 21).
5. ALTER, C. M., and MATHERS, F. C.: The Reduction of Mist or Spray from Chromium Baths by Fixed Oils Such as Fish Oil. *Monthly Review* (American Electroplaters' Soc.), pp. 11-16, June, 1934.
6. DAVIS, W. P.: Method of Reducing Chromic Acid Spray in Plating Tanks. *Safety Review*, 3:13 (May) 1946.
7. MOLOS, J. E.: Use of Plastic Chips in the Control of Chromic Acid Mist. *Industrial Medicine*, 16:8 (August) 1947.
8. STERN, A. C., BENJAMIN, L. P., and GOLDBERG, H.: The Use of Plastic Beads in Chromium Plating Tanks. *Plating*, June, 1948.
9. Ventilation and Operation of Open Surface Tanks: Code Z9.1, American Standards Association, 1951.
10. Maximum Allowable Concentrations: American Conference of Governmental Industrial Hygienist, Transactions of the 15th Annual Meeting, 1953.
11. SANDELL, E. B.: Colorimetric Determination of Traces of Metals. New York Interscience Publishers, Inc., 1944, pp. 191-195.
12. SMITH, R. G., and DIAMOND, P.: The Microdetermination of Ozone. *American Industrial Hygiene Association Quarterly*, 13:4 (December) 1952.
13. DANLE, D., BONNAR, R. V., and WICKMANN, H. J.: *Journal of the Association of Official Agricultural Chemists*, 21:3, 459 (1938).
14. FREDERICK, W. G.: Estimation of Small Amounts of Antimony with Rhodamine B. *Industrial and Engineering Chemistry*, 13:922 (December) 1941.

Formaldehyde in Air

—A SPECIFIC FIELD TEST

WILLIAM E. MacDONALD, JR., Division of Industrial Hygiene
Florida State Board of Health, Jacksonville

THE PROPOSED method for determining atmospheric formaldehyde is a modification of that used by Ozburn.[11] It involves visual comparison of the purple color developed when formaldehyde and chromotropic acid, 1,8-dihydroxynaphthalene-3,6-disulfonic acid, are heated together with sulfuric acid.

Recently when the author had occasion to measure the amount of formaldehyde in a workroom atmosphere, he found that his Schiff's reagent was not sensitive enough to detect formaldehyde in the concentration encountered. The Ozburn[11] chromotropic acid qualitative test for formaldehyde was then tried. An aliquot of the sampling medium containing the minute amount of formaldehyde was mixed with chromotropic acid followed by sulfuric acid. The results were immediate and positive. The method was found highly sensitive but the results were not quantitative.

Because such a simple procedure appeared to have possibilities as a field test, further study was undertaken in an effort to make this modification of the method quantitative. A search of the available literature revealed that this reagent had not been proposed previously as a field method for determination of formaldehyde in air.

It was found that in 1937 Eegriwe[8] first proposed chromotropic acid as a specific reagent for formaldehyde. He checked it in the presence of several other compounds including acetaldehyde. Boyd and Logan[3] used it in 1942 for determining substances which yield formaldehyde on oxidation with periodate. Their modification made the procedure quantitative. In 1945, Bricker and Johnson[4] published their work on this reagent. They modified the procedure for use

with a Beckman DU Spectrophotometer. MacFadyen,[10] working independently, published his spectrophotometric procedure during the same year. The following year Ozburn[11] applied the method to indirect detection of methanol in blood and body fluids using acid-permanganate oxidation of methanol to produce formaldehyde which was then reacted with chromotropic and sulfuric acids. Heat for the reaction was that produced by the sulfuric acid and water being mixed. In 1948 Boos[2] applied MacFadyen's spectrophotometric method to determination of the formaldehyde produced by acid-permanganate oxidation of samples containing methanol. In his "Industrial Toxicology," Fairhall[9] suggested the spectrophotometric method of Bricker and Johnson for use in the industrial hygiene laboratory. Other investigators have since adopted the reagent for determination of urinary corticosteriods,[7] of diacetyl,[12] of end unsaturation in organic compounds,[5] and of formaldehyde in milk and other foods.[1]

Specificity and sensitivity of the reaction between formaldehyde and chromotropic acid have been the main points of all papers consulted. The literature search indicates that only a few of the many compounds tested have been found to give positive interference. The literature also revealed that diacetyl, glyceraldehyde, furfural, and some sugars give colored reaction products which interfere; and that acetone, diacetone alcohol, and methyl ethyl ketone interfere with the formation of the purple color. The list of compounds which the various investigators have tested and found to give negative results includes acetaldehyde, propionaldehyde, butyraldehyde, isobutyraldehyde, isovaleraldehyde, crotonaldehyde, chloral hydrate, glyoxal, benzaldehyde and phthalaldehyde.

Fig. I.

grams of formalde-
hyde per ml. It should
be prepared shortly
before use.

DETERMINATION:

Transfer a 4.0 ml.
aliquot of the sample
to a 30 ml. Erlenmeyer
flask (or other small
container which will
permit complete and
rapid mixing), add
0.10 ml. of 1.0%
chromotropic acid, and
mix. Add with cau-
tion 6.0 ml. concen-
trated H_2SO_4 (sp.gr.
1.84), and mix thor-
oughly. Allow to cool
to room temperature
and visually compare
with standards pre-
pared using 0.1, 0.2
and so on up to 2.0
ml. of Standard Formaldehyde Solution
"B." Use distilled water to make to 4.0 ml.
volume prior to addition of chromotropic
and sulfuric acids. Color development is
complete by the time samples have cooled
to room temperature. If the sample requires
a smaller aliquot for analysis, make up to
4.0 ml. with distilled water.

Discussion

RECENTLY Bricker and Vail[6] found that
formaldehyde and chromotropic acid
react in an undertermined way to form a
complex which is stable up to about 200° C.
This characteristic permits separation from
volatile interfering compounds that evapo-
rate below 200° C.

This characteristic also permits concen-
tration of the sample by evaporation with-
out loss of formaldehyde. Therefore, if the
amount of formaldehyde in 4.0 ml. of the
original sample is too small for direct read-
ing, a concentration step may be added.
Using a suitable aliquot one should add 0.1
ml. of chromotropic acid solution and con-
centrate by evaporation. The concentrated
aliquot adjusted to 4.1 ml. is then ready for
addition of 6.0 ml. sulfuric acid and compar-
ison with standards as before.

Another advantage of this stable union is
that it permits separation of the formalde-
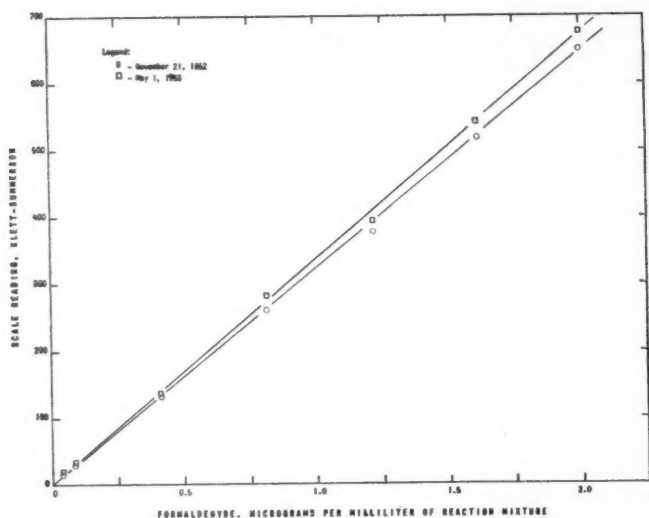
Recommended Procedure

COLLECTION OF SAMPLE: The sample is col-
lected in water using a fritted glass bub-
bler. A bisulfite or sodium hydroxide collec-
tion medium can also be used without inter-
fering with the color development.

REAGENTS:

1. Chromotropic acid, 1,8-dihydroxynaph-
thalene-3,6-disulfonic acid, Eastman Kodak
(P-1613), 1.0% aqueous solution. Ten milli-
liters of the solution are prepared, filtered,
and stored in a brown bottle. When this solu-
tion darkens it should be discarded and a
fresh supply prepared. The disodium salt,
Eastman Kodak (P-230), is now available.

2. Concentrated sulfuric acid stored in a
polyethylene plastic bottle to avoid danger
of broken bottles and spilled acid in field
kit.

3. Formaldehyde standard solution "A"
containing 1.00 g. formaldehyde per liter of
0.1 $\underline{N}$ sodium hydroxide. Paraformaldehyde
was used in this work. If formalin is used
its strength must be determined by analy-
sis before use. Solution keeps about two
weeks.

4. Formaldehyde standard solution "B"
containing 10.0 mg. formaldehyde per liter.
Dilute 10.0 ml. of Formaldehyde Standard
Solution "A" to one liter with distilled
water. This solution contains 10.0 micro-

hyde from suspended matter. Once the formaldehyde is tied up by the chromotropic acid, filtration through paper will remove dusts which would otherwise interfere with reading by charring and darkening in the presence of concentrated H_2SO_4.

The relationship of concentration of formaldehyde to transmittancy gives a straight line when read in a Klett-Summerson photoelectric colorimeter using filter No. 55. A straight line is maintained between zero and 2.0 micrograms formaldehyde per ml. of reaction mixture and a reasonably accurate estimation may be made between standards when visual comparison is used. Above this maximum the accuracy of comparison falls off. The sensitivity is remarkable. As little as 0.1 microgram of formaldehyde per ml. of sample produces a distinct color in the final mixture. The purple color is very stable. A set of standards was found to give a slope of 0.81 when first read and a slope of 0.86 when reread after being stored in the dark for a period of over six months. A graph is included.

Conclusion

THE PURPOSE of this paper has been to introduce a field method for formaldehyde which is specific, sensitive, and rapid while keeping necessary equipment at a minimum. No attempt has been made to supersede the established spectrophotometric methods for determination of formaldehyde using chromotropic and sulfuric acids.

References

1. BENNETT, H. P.: *J. A.O.A.C.*, 32:504, 1949; 33:685, 1950.
2. BOOS, R. N.: *Anal. Chem.*, 20:964, 1948.
3. BOYD, M. J., and LOGAN, M. A.: *J. Biol. Chem.*, 146:279, 1942.
4. BRICKER, C. E., and JOHNSON, H. R.: *Ind. Eng. Chem., Anal. Ed.*, 17:400, 1945.
5. BRICKER, C. E., and ROBERTS, K. H.: *Anal. Chem.*, 21:1331, 1949.
6. BRICKER, C. E., and VAIL, W. A.: *Anal. Chem.*, 22:720, 1950.
7. DAUGHADAY, W. H., JAFFE, H., and WILLIAMS, R. H.: *J. Clin. Endocrinology*, 8:166, 1948.
8. EEGRIWE, E.: *Z. Anal. Chem.*, 110:22, 1937.
9. FAIRHALL, L. T.: Industrial Toxicology. The Wil-
10. MACFADYEN, D. A.: *J. Biol. Chem.*, 158:107, 1945. liams and Wilkins Company, Baltimore, 1949, p. 350.
11. OZBURN, E. E.: *U.S. Nav. Med. Bul.*, 46:1170, 1946.
12. SPECK, J. C., JR.: *Anal. Chem.*, 20:647, 1948.

Fame for the "Tin Ear"

KENNETH E. STEWART'S invention, which his fellow researchers have dubbed the "tin ear," was the subject of a double-page, illustrated article in the Sunday supplement of the *Pittsburgh Press* on August 8, 1954. The article lauds the University of Pittsburgh School of Medicine and the Graduate School of Public Health, both of which have enlisted in a war against industrial noise. It is explained how MR. STEWART, with his cigar-box-sized instrument strapped to his back and a special microphone hooked to a miner's cap, can follow a workman around all day and determine the "noise dose" his ears receive. The "noise dose" concept was explained as a completely new approach to assessing industrial noise hazards, for which a new unit of measurement had to be devised to cope with such variables as the irregularity of the noise and the length of time the worker is exposed to the noise. Recognition is also accorded DR. ADOLPH G. KAMMER, head of the Department of Occupational Health and DR. LEO G. DOERFLER, director of the Audiology Department of the School of Medicine.

Air Pollution

NEAR AN IRON SLAG PROCESSING PLANT

J. CHOLAK, L. J. SCHAFER and D. YEAGER
Kettering Laboratory, Department of Preventive Medicine and Industrial Health
College of Medicine, University of Cincinnati

SLAG, a by-product in the operation of iron blast-furnaces, is no longer a nuisance which must be tolerated in the production of iron. In the last 30 or 40 years, many large markets for slag have been developed, so that more than 60% of the slag now produced in the U.S. is commercialized in one form or another.[1] Plants for processing this slag are generally located close to the supply. The principal operations consist in moving cooled slag to the plant, where it is segregated, crushed, classified by screening, and loaded for shipment via rail or truck. As can be imagined, these operations are extremely dusty, so that plants located near residential areas are productive of complaints on the part of the residents.

The plant involved in this investigation made a serious effort to reduce the emissions of dust, but when complaints continued to be received, a survey was made to appraise the conditions in the area. The survey is of interest because it illustrates some of the procedures and equipment useful in the investigation of problems of this type.

Procedure

THE PLANT was located about one mile from the blast-furnace, 0.4 of a mile, to the south, from a small village (population 500) and about 0.5 mile, to the east, from another somewhat larger village (population 1200). The principal complainant lived 0.4 mile directly north of the plant adjoining its premises, and the investigation, therefore, was designed to compare conditions at this point with conditions at seven other sites equally distant from the plant but located on the main points of the compass. Four other sites at various distances from the plant were also selected as sampling stations. The quantities of dust which settled out of the atmosphere at these stations were determined from samples which were collected in dirt-fall jars placed on wooden platforms at a uniform height of 10 feet above ground level. The platform at one of the stations is shown in Fig. 1. Since the plant was shut down for a three-week period, the dirt-fall collection during this period served as the control, for comparison with samples collected for equal periods of time on three different occasions when the plant was operating. The different cycles of sampling were so spaced as to cover all four seasons of the year.

The dirt-fall jars were of Pyrex glass, 12 inches high, and approximately 5.75 inches in diameter. A small amount of distilled water was added to each jar in order to prevent the collected dust from being blown out of the jar by gusts of wind. Dur-

Fig. 1.
Illustration of sampling platform at station #11.

ing the cold season, an amount of alcohol, equal to the volume of distilled water, was added to each jar to prevent freezing of the liquid contents. The jars and contents were inspected once each week during the sampling periods, at which time losses of liquid due to evaporation were made up by adding either distilled water or a mixture of equal parts of ethyl alcohol and water. At the end of each three-week period of collection, the jars were returned to the Laboratory where the total quantities of materials caught in the jars were determined gravimetrically, following evaporation of the contents to dryness and heating to constant weight. These weights were then employed to calculate the tons of dust which had settled out of the atmosphere per square mile per month. The residues were also subjected to x-ray examination and quantitative spectrographic analysis for trace metals.

Samples were collected by electrostatic precipitation once each week at four stations. One station was located near the principal complainant's home, another was at a site ½ mile farther north, and two others were at points located variably, in accordance with the direction of the wind, one directly downwind and the other upwind at distances of 0.4 mile from the plant. These samples were also analyzed gravimetrically and spectrographically.

Results and Discussion

THE DIRT-FALL data are recorded in Table I. It is obvious that plant operations contributed appreciable quantities of material to the dust which settled out of the air in the area. The highest fall-out of dust occurred at Stations 5, 6 and 7, located on the plant premises and influenced directly by the plant operations. Except for the stations in the yard of the plant, the amounts of dust which settled out of the atmosphere at all stations when the plant was shut down compared favorably with the amounts obtained in non-industrial residential areas of larger communities. The quantities of dust which settled out of the atmosphere when the plant was operating were within the range of results obtained in the residential areas of Cincinnati.[2]

Determinations of settled dust are commonly made to compare the cleanliness of different sections of a community, although there is some question as to the accuracy of such comparisons. Various factors influence the collection, and it must be recognized that the results are of value only when they have been obtained in sufficient number over periods of sufficient time to be representative of the actual situation. One of the questions often posed in this type of determination concerns the degree of correspondence of duplicate samples. When duplicate jars were set out on a platform such as was described above, their contents were found to be in excellent agreement. There was also good agreement among samples collected in jars of different size constructed of different materials set out at the same location. The data are shown in Table II.

The reproducibility of this type of sampling when employed in a long term testing

TABLE I.
TONS OF DUST-FALL PER SQUARE MILE PER MONTH AT A NUMBER OF LOCATIONS NEAR THE PLANT

Station	Distance Miles	Direction	Plant Down Dec.	Plant Operating Nov.	April	June	Average
1	0.4	N	16.2	38.6	49.8	30.8	39.7
2	0.4	NE	9.3	23.2	44.6	19.0	28.9
3	0.4	E	8.0	38.0	34.2	22.5	31.6
4	0.4	SE	8.3	20.0	32.2	22.9	25.0
5	0.4	S	12.6	52.2	61.0	30.4	47.9
6	0.4	SW	28.4	315.0	100.6	200.0	205.2
7	0.4	W	15.6	33.7	—	147.0**	90.3
8	0.4	NW	28.6*	22.2	20.5	21.1	21.3
9	0.8	N	13.6	20.8	29.1	46.2	32.0
10	0.6	W	17.7	81.0	37.7	33.8	50.8
11	1.0	SW	17.6	22.1	39.8	43.2	35.0
12	1.0	SE	8.7	16.4	35.4	36.2	30.7
	Average		15.4	56.9	44.0	54.4	53.2
	Average less stations 6 and 7		33.5	38.4	30.6	34.3

*Based on two day collection. **Birds interfered with sample.

TABLE II.
COMPARABILITY OF DUST-FALL SAMPLES COLLECTED IN TWO JARS AT THE SAME STATION (TONS/SQUARE MILE/MONTH)

Jar No. 1	Jar No. 2	Difference Jar No. 1—Jar No. 2
58.0	61.5	—3.5
31.0	31.4*	—0.4
29.4	26.4	+3.0
13.0	13.6*	—0.6
27.6	32.8	—5.2
8.4	8.1	+0.3
8.2	8.9	—0.7
18.9	19.9	—1.0

*Jars were of different materials and sizes.

TABLE III.
DUST-FALL IN AN AREA NEAR A RAILROAD YARD (16 MONTHLY COLLECTIONS)

Station	Tons of Dust-Fall per Month per Square Mile Average	Range
1	38.7	22.8—53.5
2	20.3	11.8—36.6
3	19.0	11.5—30.5
4	8.6	4.0—11.9
5	13.7	9.6—18.1
6	10.1	4.3—16.3

program, is further indicated in Table III which presents data from a soot-fall investigation in an area near a railroad yard. The trend indicated by the average values is confirmed by the ranges of values obtained during this investigation. Although the ranges of values show some overlapping, the quantities of settled dust obtained at the several stations during the same period of collection followed consistently the order shown by the average values in the table. Therefore, we are convinced that the average quantities of settled dust found in prolonged investigations of this type are satisfactory measures of the relative cleanliness of different communities or sections of the same community. This type of sampling is particularly useful for the investigation of industrial pollution of the atmosphere with dusts, since it generally furnishes sufficient quantities of material for examination by other methods.

The pin-pointing of the origin of settled dust in order to fix direct responsibility for it, is not an easy matter, since characteristic materials are not always present or may be masked to an extent which precludes definite proof of responsibility. Fortunately, characteristic materials were present in the dust in this investigation, so that an

approximate estimation of the contribution of the plant to the total pollution in the area could be made. The method of attack is described here because it points up the ease and certainty with which this can be done with suitable analytical equipment.

The blast-furnace slag, removed as rafter dust from the plant, when analyzed by a powder x-ray diffraction technique was shown to consist principally of akermanite ($2CaO \cdot MgO \cdot 2SiO_2$) with some gehlenite ($2CaOAl_2O_3 \cdot SiO_2$). The lines of akermanite, therefore, were to be expected in x-ray patterns of samples obtained where this material was deposited, and its presence in the dust constituted definite evidence of its origin. All samples of settled dust, therefore, were subjected to x-ray analysis. The results were consistent and are illustrated in Fig. 2 which gives the data for one station only. The principal akermanite lines are marked in spectrogram A (rafter dust). These lines are absent in spectrogram B— for material collected when the plant was
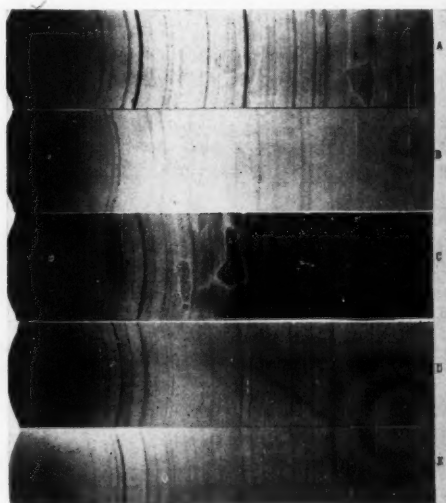

Fig. 2.
Comparison of x-ray patterns of dust-fall collected at station #12: (A) Rafter dust from the plant showing the three strongest lines of akermanite. (B) Material collected when plant was shut down (December, 1952). (C) Material collected when plant was operating (November, 1952). (D) Material collected when plant was operating (April, 1953). (E) Material collected when plant was operating (June, 1953).

shut down but are distinct in C, D and E which are spectrograms of material collected when the plant was operating. These observations offer further proof that dust from the plant operations occurred in the settled dust in samples collected in the area.

Exploratory examinations of the x-ray spectra obtained for each sample revealed a uniformity in the qualitative composition of the crystalline material collected at all of the stations. The results are given in Table IV. The only exceptions were the November collection at Station 6, and the June collection at Station 7. The November collection at Station 6 contained large quantities of merwinite ($3CaO \cdot MgO \cdot 2SiO_2$). The presence of merwinite could be attributed to the processing of granulated

TABLE IV.

CRYSTALLINE MATERIAL PRESENT IN DUST-FALL AS DETERMINED FROM THE X-RAY DIFFRACTION PATTERNS

Station	Plant Down	Plant Operating		
	December 1952	November 1952	April 1953	June 1953
1	+++ ++++ $CaSO_4$, Fe_2O_3, +++ ? SiO_2, B.F. Slag	+ + $CaSO_4$, Fe_2O_3, + +++ SiO_2, B.F. Slag	+ + $CaSO_4$, Fe_2O_3, +++ +++ SiO_2, B.F. Slag	+ ++ $CaSO_4$, Fe_2O_3, +++ +++ SiO_2, B.F. Slag
2	+++ ++++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag	++ ++ $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag	++ + $CaSO_4$, Fe_2O_3, ++++ +++ SiO_2, B.F. Slag	++ ++ $CaSO_4$, Fe_2O_3, ++++ +++ SiO_2, B.F. Slag
3	+++ ++ $CaSO_4$, Fe_2O_3, +++ ? SiO_2, B.F. Slag	+ + Fe_2O_3, SiO_2, + B.F. Slag	+++ ++ $CaSO_4$, Fe_2O_3, ++++ +++ SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++++ +++ SiO_2, B.F. Slag
4	+++ ++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++ + SiO_2, B.F. Slag	+++ ++ $CaSO_4$, Fe_2O_3, ++++ ++ SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, +++ +++ SiO_2, B.F. Slag
5	+++ ++ $CaSO_4$, Fe_2O_3, +++ ? SiO_2, B.F. Slag	+++ ++ $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag	+ ++ $CaSO_4$, Fe_2O_3, ++++ + SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++ ++++ SiO_2, B.F. Slag
6	++ +++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag	++ ++++ $CaSO_4$, $Ca_3Mg (SiO_4)_2$, + + SiO_2, B.F. Slag	++ + $CaSO_4$, Fe_2O_3, +++ ++++ SiO_2, B.F. Slag	Trace + $CaSO_4$ SiO_2, ++++ B. F. Slag
7	++ +++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag	+++ +++ $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag		+++ $Ca_3 (PO_4)_2$, +++ + SiO_2, B.F. Slag
8		+++ + $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag	+++ ++ $CaSO_4$, Fe_2O_3, ++++ ++ SiO_2, B.F. Slag	++ + $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag
9	++ +++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag	+++ ++ $CaSO_4$, Fe_2O_3, ++ +++ SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++++ + SiO_2, B.F. Slag	+ + $CaSO_4$, Fe_2O_3, ++++ ++ SiO_2, B.F. Slag
10	+++ ++ $CaSO_4$, Fe_2O_3, +++ ? SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++ ++ SiO_2, B.F. Slag	++ + $CaSO_4$, Fe_2O_3, ++++ ++ SiO_2, B.F. Slag	++ +++ $CaSO_4$, Fe_2O_3, ++++ ++ SiO_2, B.F. Slag
11	++ +++ $CaSO_4$, Fe_2O_3, ++ ? SiO_2, B.F. Slag		++ + $CaSO_4$, Fe_2O_3, ++++ + SiO_2, B.F. Slag	++ ++++ $CaSO_4$, Fe_2O_3, +++ Trace SiO_2, B.F. Slag
12	+++ ++ $CaSO_4$, Fe_2O_3, +++ ? SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, ++ + SiO_2, B.F. Slag	++ + $CaSO_4$, Fe_2O_3, ++++ + SiO_2, B.F. Slag	+++ + $CaSO_4$, Fe_2O_3, +++ Trace SiO_2, B.F. Slag

slag at the site, in which a high-pressure water jet was used to quench the slag as it was discharged into the pit from the thimble. The calcium phosphate present in the sample collected at Station 7 during June was due to bird-droppings which had contaminated this particular sample.

X-ray spectra may generally be used for quantitative purposes, but the lack of a calibration curve for akermanite, together with the availability of another material in the slag which could be followed by analytical means, led to the use of the latter procedure to determine the amount of blast-furnace slag in the settled dust in the area. This substance was manganese oxide, which was found to be present in the slag in the concentration of 1%. Many analyses of settled dust, collected in the Cincinnati area had indicated that the average manganese oxide content of such dust was only 0.05%. An estimation of the quantity due to the slag, therefore, could be arrived at from the quantities of manganese oxide in excess of 0.05% present in the deposit, the known manganese oxide content of the slag, and the total quantity of dust collected in each jar. The manganese oxide determinations are listed in Table V, where it may be seen that there was a marked increase in the manganese oxide content of the settled dust collected when the plant was operating. The quantities of settled dust due to blast-furnace slag have been tabulated in Table VI. The data show that only 8.5% of the average dirt-fall in the area was due to blast-furnace slag when the plant was shut down. However, when the plant was operating, 30% of the average dirt-fall in the area was due to blast-furnace slag. The amounts of blast-furnace slag deposited at the individual stations varied from 8.5% at Station 12, not directly affected, to a maximum of 53% at Station 6 at the center of the plant activities. At Station 1, where the complaint arose, nearly 26% of the average amount of dirt-fall was due to blast-furnace slag.

Table VII lists the quantities of suspended matter obtained at the two stations which were most often downwind from the plant. The station nearer to the plant was often affected by plant operations, as indicated by the high average values and the ranges of the quantities of suspended particulate

matter which were obtained when the plant was operating. The percentage of the total suspended particulate matter due to plant operations is given for purposes of comparison in Table VIII for two of the stations. The samples taken downwind from the plant clearly indicate that much of the

TABLE V.
PERCENTAGE MANGANESE OXIDE IN
DUST-FALL SAMPLES

| | Plant Down | Plant Operating | | |
Station	Dec.	Nov.	April	June	Average
1	0.16	0.42	0.27	0.22	0.30
2	0.14	0.47	0.34	0.27	0.36
3	0.13	0.13	0.36	0.20	0.23
4	0.02	0.24	0.18	0.47	0.30
5	0.18	0.33	0.19	0.63	0.38
6	0.17	0.61	0.32	0.65	0.53
7	0.18	0.40	—	0.08	0.24
8	0.03	0.24	0.23	0.40	0.29
9	0.14	0.39	0.16	0.10	0.22
10	0.16	0.20	0.31	0.37	0.29
11	0.21	0.04	0.43	0.49	0.32
12	0.09	0.20	0.15	0.10	0.15
Average	0.13	0.31	0.27	0.33	0.30

TABLE VI.
TONS OF DUST-FALL PER SQUARE MILE PER
MONTH DUE TO BLAST-FURNACE SLAG

| | Plant Down | Plant Operating | | |
Station	Dec.	Nov.	April	June	Average
1	1.8	14.5	11.0	5.3	10.3
2	0.8	9.8	13.1	4.2	9.0
3	0.6	3.1	10.7	3.4	5.7
4	0	3.9	4.2	9.7	5.9
5	1.7	14.8	8.7	17.8	13.8
6	3.4	178.0	27.3	121.0	108.8
7	2.0	11.9	—	4.4	5.4
8	0	4.3	3.7	7.5	5.2
9	1.2	7.2	3.2	2.3	4.2
10	2.0	12.3	9.9	11.0	11.1
11	2.8	0	15.3	19.2	11.5
12	0.4	2.5	3.6	1.8	2.6
Average	1.3	21.9	10.1	17.3	16.1
Average less station 6		7.7	8.3	7.9	7.7

TABLE VII.
AVERAGE AND RANGE OF QUANTITIES OF
PARTICULATE MATTER IN THE ATMOSPHERE
AT A NUMBER OF STATIONS IN THE AREA
ADJACENT TO THE PLANT

| | Milligrams per Cubic Meter | |
Sampling Period	4/10 Mile North of Plant	8/10 Mile North of Plant
December*	0.203	0.138
	(0.176-0.222)	(0.142-0.159)
November	0.762	0.270
	(0.124-1.980)	(0.062-0.477)
April	0.303	0.155
	(0.220-0.470)	(0.082-0.260)
June	0.169	0.162
	(0.099-0.272)	(0.052-0.366)
*Plant not operating.		

TABLE VIII.
PERCENTAGE OF PARTICULATE MATTER DUE TO
BLAST-FURNACE SLAG IN THE ATMOSPHERE AT
TWO STATIONS IN THE AREA ADJACENT TO THE
SLAG PLANT

Sampling Period	4/10 Mile North of Plant	4/10 Mile Down-wind of Plant
December*	0.05	0.05
November	25.00	68.00
April	46.00	100.00
June	0.05	34.80

*Plant not operating.

TABLE IX.
PERCENTAGE OF FREE CRYSTALLINE SILICA
(SiO_2) IN SETTLED DUST

Composite Stations	Per Cent Free Crystalline Silica
1, 2, 3	11.0
4, 5, 6	3.5
7, 8	< 2.5
9	11.5
10, 11	11.7
12	10.6
Average	8.5

suspended matter in the air had its origin
in the plant. During two of the sampling
periods, when the plant was operating, the
suspended matter at Station 1 also was
composed largely of particles of blast-
furnace slag. The low value in June may be
accounted for on the basis of shifting winds,
which caused the stations to be upwind
rather than downwind from the plant at
the time these samples were collected. The
calculations listed in Table VIII were based
on the observation that the average manga-
nese oxide content of the suspended matter
in the Cincinnati atmosphere was 0.031%
and that particles of slag less than 10 mi-
crons in size, which are those most likely to
remain suspended in the atmosphere, con-
tained 1.29% manganese oxide.

All of the evidence, therefore, indicated
that the contribution of the plant to the
pollution of the area, as measured by the
quantities of settled dust and by the quan-
tities of matter suspended in the atmos-
phere, was considerable, although, the
total pollution was not excessive as
compared to that of other industrial
cities. It is of interest to note, further,
that the area involved in this survey is
honeycombed with extensive sand and gravel
pits, and that this feature was reflected in
the x-ray patterns by the relatively strong
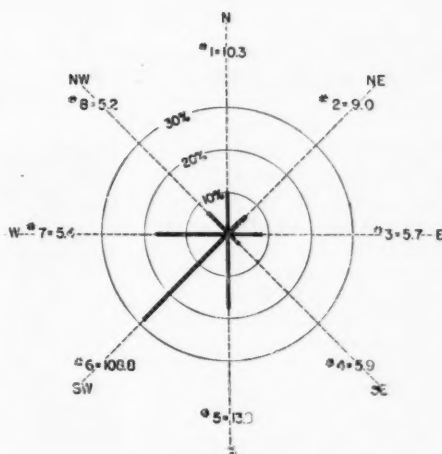lines of quartz in the samples obtained at

Fig. 3.
Wind rose diagram for daylight hours during
all sampling days.

all stations whether the plant was shut
down or being operated (Table IV). Table
IX gives the free crystalline silica in the
dirt-fall as determined from composite
samples of the stations. Except for Stations
4 through 8, in or near the plant yard, the
amounts of free crystalline silica in the
settled dust of the area were somewhat
larger than those found in samples of soot-
fall in the Cincinnati area.[3]

Wind-rose patterns for the area, shown
in Fig. 3, indicate clearly that winds from
the south to the southwest directly affected
Stations 1 and 2, which were in the area
from which complaints came. This area was
downwind from the plant approximately
50% of the time. Although the data ob-
tained during this investigation prove by
several different methods that the plant
contributed a considerable portion of the
pollution in the area, the wind-rose data are
extremely useful in showing the role of
meteorological factors in confirming or dis-
proving the validity of complaints concern-
ing the effluents from specific sources.

References

1. JOSEPHSON, G. W., SILLERS, JR., F. and RUNNER,
D. G.: Iron Blast-Furnace Slag. Bulletin 479, Bureau of
Mines, Washington, D.C., 1949.

2. Bureau of Smoke Inspection: Atmospheric Pollu-
tion Survey. Year, 1952. Cincinnati, Ohio.

3. CHOLAK, J., SCHAFER, L. J. and HOFFER, R. F.:
Results of a Five-Year Investigation of Air Pollution in
Cincinnati. *Arch. Ind. Hyg. Occup. Med.*, 6:314, 1952.

✦ President's Page

DURING the 1954 Annual Meeting, HENRY F. SMYTH, JR., announced his intention to resign as Executive Secretary of AIHA, effective not later than June, 1955. This notice has made it necessary to formulate plans for filling the vacancy, or making other arrangements for handling the affairs of the Association.

At the annual business meeting, amendments to the Constitution and By-Laws were proposed which would provide for contributing or sustaining memberships. This action was taken to provide the mechanics for increasing Association income from other sources than membership dues, if necessary. The amendment was approved at the business meeting and it has since been circulated to the entire membership for vote. The results of this vote have been tabulated and the amendment was approved by a large majority.

The AIHA has reached a stage of development where many of its activities tax the volunteer contributor to the limit. The time and effort which goes into the QUARTERLY, for example, is greater than is realized by many of our members. Any increase in the size of the QUARTERLY or frequency of publication would further increase the work of its editors. The last President's Page announced plans for the appointment of technical committees in our specialty fields. These committees now are functioning, and as reports are prepared for publication, the volunteer work load will become even greater. While much of the work volume of the Executive Secretary's office is routine, the resignation of HENRY F. SMYTH will create a void in leadership which has been so ably provided. The leadership provided by any one President extends over a short term of office which limits the scope of his accomplishments, with no assurance that his program will be continued after he has completed his term. The importance of continuity of purpose, policy, and technical activity are difficult to measure. However, these items are essential to progress and growth of any organization, whether it be business or professional. Thus, any plan for AIHA reorganization must thoroughly consider all of these factors along with financial matters.

It was with these thoughts in mind that an Organizational Committee was appointed and charged with the following duties: (1) To consider the necessary reorganization within AIHA to provide for handling Association matters after the present Executive Secretary completes his term. (2) To develop a plan for AIHA financing. (3) To consider other matters related to the above.

The Organizational Committee has held one meeting, however, a report has not been received. Findings of this committee will be presented to the Board of Directors for action, either by letter ballot or at its regular meeting in November. Presently it is impossible to predict either the final plans for continuing the Executive Secretary's office, or a date for putting any necessary reorganization into effect.

HENRY SMYTH voluntarily became Executive Secretary in 1947. He has served continuously since that time, without remuneration from the Association. He has given generously of his time for the promotion and development of the industrial hygiene profession. The AIHA owes DR. SMYTH a debt of gratitude which will be difficult to repay. On behalf of every AIHA member I should like to thank HENRY SMYTH and Mellon Institute for the many contributions over the past seven years.

As a result of this special Executive Secretary arrangement, AIHA has operated on a minimum budget and the dues have been kept at an unbelievably low figure in comparison to those of other professional societies. Whatever the plan eventually adopted for continuing the Executive Secretary's office, we may expect increased operating ex-

penses. We should consider an increase in membership dues an essential and worthwhile step toward the further development of our profession. Many members have already urged your officers to propose a dues increase. As a result, consideration is now being given to such an increase and the matter will be proposed at the annual business meeting in April, 1955. If approved at the business meeting, an amendment will be circulated to the membership for vote.

—HERBERT T. WALWORTH

◆ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE FOLLOWING is a partial list of articles, by titles and authors, from journals received by the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION since the June, 1954 issue of the Quarterly in exchange for copies of the Quarterly. Additional information on any of the journals or articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13.

I. LA MEDICINA DEL LAVORO (ITALY). Vol. 45, No. 3 (1954).

On Chloracne. V. Puccinelli, pp. 131 to 145.

A report and description of three cases of chloracne caused by the aromatic hydrocarbon-pentachlorodiphenyl. The theory is advanced that chloracne is produced by absorption through the gastroenteric or inhalatory routes.

Occupational Poisoning from Phosphorus Oxychloride. C. Sassi, pp. 171 to 177.

II. LA MEDICINA DEL LAVORO (ITALY). Vol. 45, No. 4 (1954).

The Aminoacid Composition of the Proteins Composing the Hyaline Substance of Silicotic Nodules. B. Pernis and Pecchiai, pp. 205 to 213.

Alterations of the Eye in Chronic Mercury Poisoning. Clinical and Experimental Research Results. G. Baldi, B. Marengbi and A. Picollo, pp. 214 to 224.

Blood Coagulation Process in Silicosis. E. Sartorelli, S. Cambruzzi and C. Bellamio, pp. 225 to 231.

The Maximum Breathing Capacity Test in Silicosis. E. Sartorelli, pp. 232 to 238.

Health Hazards in a Tartaric Acid Factory. M. Barsotti, C. Sassi, and G. Ghetti, pp. 239 to 249.

III. ARHIV ZA HIGIJENU RADA (YUGOSLAVIA). Vol. 5, No. 1 (1954).

Investigations on the Fate of Cadmium in the Body During the Course of Poisoning. R. Truhaut and C. Boudene, pp. 19 to 48.

A microdetermination method for cadmium involving nephelometry is presented. It was used to study the distribution and excretion of this material. The authors conclude from this elimination experiment that cadmium is a cumulative poison.

First Cases of Asbestosis and Simple Pneumoconiosis caused by Coal Dust in Yugoslavia. M. Stojadinovic', pp. 57 to 76.

IV. CHRONICLE OF THE WORLD HEALTH ORGANIZATION. Vol. 8, No. 1 (1954).

Resistance of Insects to Insecticides. Pp. 3 to 6.

V. IBID. Vol. 8, No. 2-3 (1954).

Control of Treponematosis. Pp. 39 to 108.

VI. IBID. Vol. 8, No. 4 (1954).

Report of Expert Group on Alcohol as a Drug. Pp. 144 to 146.

VII. IBID. Vol. 8, No. 5 (1954).

Review of Work of WHO: 1953. Pp. 157 to 181.

VIII. IBID. Vol. 8, No. 6 (1954).

IX. J. OF SCIENCE OF LABOUR (JAPAN). Vol. 30, No. 5 (1954).

Chloronitrobenzene Poisoning. S. Kubota, S. Nomura and S. Ishizu, pp. 283 to 301.

◆ Books

FLOW AND FAN—PRINCIPLES OF MOVING AIR THROUGH DUCTS: C. HAROLD BERRY. The Industrial Press, New York, 1954, pp. 226, $4.00.

This is not a book on the design of industrial exhaust ventilation systems. Rather, it

is a discussion on the theory of air flow through ducts and fans with examples of some of the difficulties or pitfalls involved in some aspects of design. This book is not a substitute for the presently available manuals on industrial exhaust systems utilized by the industrial hygiene, plant or ventilation engineer but will have its principal value to the engineer faced with unusual ventilation problems which require the determination of the various resistances within closer tolerances than generally is allowable within the limits of practice. Therefore, while it is one of interest to all ventilation engineers, it will have limited use in daily design practice for the design engineer who must, by reason of economy, practicality and time, apply empirical knowledge to his design problems.

A complete discussion on industrial exhaust systems is not contained herein. For example, hood design, which is a most important feature of exhaust ventilation systems, has been omitted. This was done possibly in line with the author's intent to treat topics, upon which information is readily available, with brief mention. However, if this be the case, it is difficult to understand why the author devotes about one-half of the book to the subject of fans. It is felt that the mathematical treatment of underlying theory, while simple, is too extensively treated and could be condensed. The short discussion on effect of flanges, on page 99, is far too brief and should have been part of a chapter on hood design. The reviewer feels that too much space has been devoted to the subject of losses in converging and diverging passages.

Greater use could have been made of actual problems and illustrations. The first chapter could well have included a discussion of the principles of air flow in which the various pressures involved in air flow through a ventilation system are graphically presented. This would have been of assistance to the engineer in providing him with a better understanding of the relationship between total, static and velocity pressures and their alteration from one end of the systems to the other. Then, the author's discussion in Chapter 1 would be more readily understood by those engineers whose responsibilities in ventilation design is only one of several engineering tasks.

This book is written for all those who have design problems in fluid flow, both pressure systems and exhaust systems. Therefore, the industrial hygiene engineer, devoting his design efforts solely to exhaust systems, will find paragraphs which, at the moment, do not apply to his field. For example, on page 52, the discussion of a duct carrying one gas, and later another type of gas, rarely, if ever, arises in industrial hygiene and would be contrary to state codes.

It is felt that the organization of the material (which is largely a compilation of a series of articles by the author which have appeared in *Heating and Ventilating*) and its mechanical presentation for publication could have been improved. Some of the tables, especially those on pages 31, 33 and 53, are somewhat difficult to read for the presbyopic engineer.

The reviewer does want to indicate that the book is one which any design engineer can use to improve his knowledge of air flow and the various pressure losses which occur in duct systems. The book is not one devoted entirely to theory, in fact the author provides several excellent warnings, of pitfalls, which the designer should recognize. The author points out that in industrial exhaust ventilation design, the practice of basing all computations on static pressures, without consideration of total pressure, may be puzzling to the beginner. The effect of elevation on static pressure readings is also well discussed, although this effect is of minor significance to the designer of industrial exhaust systems.

Several useful tables and charts are presented—for example, those on frictional equivalent round and circular ducts and the chart on fifth powers of diameter ratios. These will simplify the determination of duct sizes to balance friction losses. The information on losses in elbows is well explained, as is the discussion on system resistance and pressures, system power and static horsepower. The sections on fans, although containing a sprinkling of dimensional analyses, should be of considerable value to the design engineer. The plant engineer who is faced with ventilation problems and who must undertake to design systems could well afford to thoroughly peruse this book. In addition, the industrial hygienist, who has a responsibility for ventilation, will also find much value in this text.

In conclusion, this book can principally be used as a supplement to, and not a substitute for, the presently utilized exhaust ventilation guides.   —KENNETH M. MORSE

Beaver Committee Reports

COMMITTEE ON AIR POLLUTION: *Interim Report.* H.M. Stationery Office (London), 1s. 6d.

In December 1952 more than 4,000 people died in Greater London as the result of a four-day smog. On the 21st of July, 1953, Her Majesty's Government appointed a Committee on Air Pollution "to examine the nature,

causes and effects of air pollution and the efficacy of present preventive measures; to consider what further preventive measures are practicable; and to make recommendations." This committee, commonly called, after its Chairman, the Beaver Committee, is living up to its name. Early in December its Interim Report was presented to Parliament by command of Her Majesty.

The committee has, thus far, called no evidence and this workmanlike report gives a brief survey of the present knowledge in this matter and includes some emergency recommendations, that may appear as counsels of despair, but some of which have already been put into effect. The Report does, however, give a great many basic facts and figures, upon which a reasoned discussion of long-term measures must be based. Particularly important in this respect, perhaps, is Table 5, which gives the main uses of solid fuel in Great Britain in 1952 and estimates of the pollution so caused. This shows, for example, that 204.7 million tons of raw coal were burnt or carbonized to produce 2.1 million tons of smoke, 0.7 million tons of grit and 5.0 million tons of SO_2. Of the smoke, 0.9 million tons were produced by the domestic consumer; 0.8, by industry; and the remainder, by the railways. Of the SO_2, the domestic grate is responsible for only about 0.9 million tons against industry's 1.8 and power-stations' 1.0.

In the light of these figures, and in view of the acknowledged difficulty of weaning the Briton from his barbarous open fire, it is interesting to note that the committee writes (§5) "Both medical opinion and chemical investigation indicate that the deleterious effects of the oxides of sulphur are greatly enhanced by the presence of smoke particles and our conclusion, therefore, is that *the first objective should be to prevent the emission of coal smoke and oil smoke,* and of grit." This recommendation would seem to receive some support from the recent work of La Belle. It appears, however, that the importance of sulphur compounds in damaging health as shown by Professor Drinker, Dr. Mary Amdur and their colleagues at Harvard, has not been fully appreciated in Britain. Too often only smoke and grit are considered as requiring abatement, with the result that some £600 millions were spent on electrical development in 1945-51—and this though power-stations will aggravate the sulphur problem in their own localities—rather than on the gas industry which considerably reduces the sulphur emitted.

The Report also gives an authoritative review of the disastrous fog episode of December, 1952, which provided the stimulus for its appointment.

The cost of atmospheric pollution in Britain is estimated as being £100-150 millions p.a. Even a moderate proportion of this, therefore, invested in capital improvements designed to reduce air pollution, would pay handsome dividends.

Among the longer-term preventive measures commended by the Committee are the provision of smokeless solid fuel in adequate quantities for the domestic user, smokeless zones, and district heating. St. Louis, Pittsburgh and other American cities are called in evidence to show that large smokeless zones are possible and effective.

"This preliminary Report has outlined the main features of the problem of air pollution as it exists today. The causes and remedies of pollution by smoke are known: the problem is one of practicability and economics, and of the education of the whole community." This report, then, can be taken as an earnest of goodwill. We may hope that the Beaver Committee will feel itself sufficiently supported by informed public opinion to produce a bold final report and that it will not allow itself to ignore the great importance to health of the oxides of sulphur. —PETER C. G. ISAAC
Newcastle upon Tyne

✦ *Obituary*

WILLIS G. GREEN, 39, a leading Southern California chemist and air pollution technologist, died May 23, 1954. Born in Pasadena, MR. GREEN made his home in Alhambra for 30 years. Nationally known for his work in air and water pollution, he was Chairman of General Petroleum's Committee on Air Pollution Problems and had worked on a similar committee for the Western Oil and Gas Association. He was a member of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, the American Chemical Society, the Franklin Society of Chemical Engineers, the General Petroleum Air Pollution Control Association and the American Petroleum Institute.

✦ News of Local Sections

Utah Section

THE UTAH SECTION held its quarterly meeting May 12 at the University of Utah. DR. M. D. THOMAS, originator of the Thomas Autometer, spoke on the subject "Some Health Aspects of Air Pollution."

During May, June, and July, the Utah Section sponsored a series of radio and television programs designed to acquaint the general public with Industrial Hygiene and Occupational Medicine. The programs were as follows:

May 1—"Industrial Hygiene and Occupational Medicine, Early History"—PRESTON J. BURNHAM, M.D., Industrial Physician and Surgeon.

May 17—"History of Occupational Medicine and Application to People of Utah"—PRESTON J. BURNHAM, M.D.

May 22—"Home and Farm Hygiene"—E. ELBRIDGE MORRILL, JR., Director, Division of Occupational Health, Utah State Department of Health, and RICHARD D. COLEMAN, Senior Assistant Sanitary Engineer, Occupational Health Field Station, U.S. Public Health Service.

May 29—"Industrial Nursing"—BEATRICE MCHARG, R.N., Industrial Nursing Consultant, Division of Occupational Health, Utah State Department of Health, and ADA BURT, R.N., Assistant Professor, College of Nursing, University of Utah.

June 12—"Industrial Hygiene, Recent History and Application"—D. E. RUSHING, Principal Chemist, and DUNCAN A. HOLADAY, Acting Chief, Occupational Health Field Station, U.S. Public Health Service.

June 12—"Federal and State Industrial Hygiene Programs"—E. ELBRIDGE MORRIILL, JR., Director, Division of Occupational Health, Utah State Department of Health, and LEWIS J. CRALLEY, PH.D., Chief, Occupational Health Field Station, U.S. Public Health Service.

June 13—A panel was presented on management's interest in Industrial Hygiene and Occupational Medicine with the following speakers: PRESTON J. BURNHAM, M.D.; LEWIS J. CRALLEY, PH.D.; GEORGE A. SPENDLOVE, M.D., Director of Public Health, Utah State Department of Health; and JAMES K. RICHARDSON, Assistant to General Manager, Utah Copper Division, Kennecott Copper Corporation.

June 14—"Industrial Commission Function in Industrial Hygiene"—OTTO WIESLEY, Chairman, Utah State Industrial Commission.

June 16—"Occupational Medicine"—PRESTON J. BURNHAM, M.D. and PAUL S. RICHARDS, M.D.

July—"Industrial Hygiene"—FRANCIS MORTENSON, PH.D., Chief Hygienist; B. J. LARSON, M.D., Plant Physician; and FRANK DAIN, Director of Industrial Relations, Columbia-Geneva Steel Division, U.S. Steel Corporation.

Western New York

THE WESTERN New York Section held its annual meeting on March 4. The results of the election were announced: President—HAROLD

The television camera focuses on Preston J. Burnham, M.D. (right), chairman of the Utah Section radio-television program as he makes the introductory remarks. R. L. Servatius (left) acted as moderator.

Dr. Lewis J. Cralley (left), Chief, Division Occupational Health Field Station, demonstrates to the television audience a millipore dust and fume sampling apparatus as Mr. Servatius asks pertinent questions.

w. CROUCH, Eastman Kodak Company; President-Elect—EDWARD C. RILEY, M.D., Eastman Kodak Company; Secretary-Treasurer—ROBERT H. WILSON, University of Rochester.

The program for the evening consisted of a discussion of some of the problems, solved and unsolved, in the design and operation of a radio-toxicity laboratory intended for the use of alpha emitters. With HAROLD C. HODGE, Ph.D. as moderator, ROBERT H. WILSON spoke on "Ventilation Control" in terms of pressure gradients, off gas cleaning, and continuous maintenance of exhaust; GERALD J. MILLER discussed the problems associated with the disposal of "hot" water and radioactive carcasses and feces; and DONALD A. MORKEN covered the difficulties encountered in setting up an atmosphere of radon free of daughter products in connection with his current investigations of the toxicity of radon. All speakers are on the staff of the University of Rochester, Atomic Energy Project.

St. Louis Section

THE ST. LOUIS SECTION met May 25 and heard DR. RAYMOND C. SUNDERMAN, Medical Director, U.S. Defense Corporation, St. Louis Ordnance Plant. DR. SUNDERMAN presented an illustrated discussion of his experiences and efforts in proper job placement and job rehabilitation for handicapped individuals. The presentation is being considered for the preparation of a movie entitled "This Could Be Your Life."

Rocky Mountain Section

THE FIRST issue of the Rocky Mountain Section Newsletter was published May 1. It was pointed out that a newsletter was of particular value because the section covers an area of about one-third of the United States. Frequent meetings cannot be held because of the distance. The section is donating subscriptions to the AIHA Quarterly to ten colleges and universities.

Metropolitan New York

THE JUNE meeting of the Metropolitan New York Section was held jointly with the Sanitary Engineering Group of the American Society of Civil Engineers. The program was a panel discussion on the subject, "A Practical Approach to Air Pollution Control." LEONARD GREENBURG, M.D., Commissioner of Air Pollution Control, City of New York, acted as moderator. The members of the panel were: WARREN W. LACY, M.D., Republic Aviation Corporation, Farmingdale, Long Island; KENNETH KUGEL, Chief Engineer, Government of the District of Columbia; JOHN P. BRADY, Edel Laboratories, Newark, N.J.; JOHN M. KANE, American Air Filter Company, Louisville, Kentucky.

◆ *In the News*

CLARK D. BRIDGES joined the staff of the American Medical Association Council on Industrial Health on June 1, 1954. MR. BRIDGES will be concerned with those aspects of the work of the Council which deal with scientific development, research and its application, clearing house services, reports on new developments, and liaison with allied non-medical scientific bodies. He will pay particular attention to selective placement and job evaluation. His book, "Job Placement of the Physically Handicapped," is a standard reference in this field. MR. BRIDGES is a member of the American Society of Safety Engineers, the Veterans of Safety, and the President's Committee on Employment of the Physically Handicapped. He is a charter member of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION and was the first President of the Chicago Section. During the past 10 years, he has been head of safety engineering, industrial hygiene, and health and safety education services for the Zurich-American Insurance Companies, Chicago.

WILLIAM T. INGRAM has established a consulting practice in Sanitary Engineering in New York City. Effective September 1, his home office will be 20 Point Crescent, Whitestone 57, New York. His laboratory office is at 148 Islip Avenue, Islip, Long Island, New York, % South Shore Laboratories. His practice will be directed primarily to the environmental problems of industry, including: air pollution control, industrial hygiene and safety, water supply, sewage disposal, refuse disposal, and other sanitation practices.

PROFESSOR INGRAM will continue his association with New York University, College of Engineering, as Adjunct Professor and will serve as a project director with the Research Division of the University on Sanitary Engineering, Industrial Health and Safety, and Air Pollution Control Research.

LUMBERMENS MUTUAL Casualty Company recently opened a new and modern industrial hygiene research laboratory, which is under the direction of HERBERT T. WALWORTH, director of industrial hygiene for the Kemper companies. The new laboratory will be used for advanced research into the elimination of industrial health hazards and for study of special related problems.